



Letter-Sound Knowledge as a Foundational Component of Emergent Literacy and Early Reading Acquisition: A Narrative Review of Recent Evidence (2021–2026)

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Abstract:

Background: Letter-sound knowledge the ability to map spoken phonemes onto their corresponding written graphemes is among the most consistently replicated early predictors of reading acquisition in alphabetic orthographies, with parallel evidence for letter-name knowledge in at least one syllabic orthography (Japanese Hiragana).

Objective: This narrative (non-systematic) review synthesizes peer-reviewed research to examine the theoretical grounding, predictive validity, instructional malleability, and neurodevelopmental correlates of letter-sound knowledge as a core component of emergent literacy.

Methods: The review synthesizes literature published between 2021 and 2026, identified through searches of [databases to be specified] using [search terms to be specified] and screened against stated inclusion and exclusion criteria, resulting in the inclusion of [N] sources. Evidence was compiled across longitudinal, intervention, cross-linguistic, and neuroimaging study designs.

Results: Evidence across the included studies yields three key findings. First, letter-sound knowledge is an early-emerging foundational skill that, together with phonological awareness and rapid automatized naming, serves as one of the strongest predictors of later decoding and word-reading outcomes. Second, instructional approaches that integrate letter-sound correspondence with phonemic awareness are associated with significantly larger gains than oral-only phonological training. Third, the developmental trajectory of letter-sound learning varies according to orthographic transparency, bilingual status, socioeconomic context, and specific access needs, including those of children who use augmentative and alternative communication.

Conclusion: These findings carry important implications for early screening, curriculum sequencing, and instructional dosage, while highlighting priority directions for future research.

Keywords: Alphabetic Principle, Dyslexia Risk, Emergent Literacy, Letter Sound Knowledge, Phonemic Awareness

1. INTRODUCTION

Emergent literacy refers to the constellation of language, symbol, and print-related skills that children develop prior to and alongside formal reading instruction, including phonological awareness, print concepts, oral language, and knowledge of letter names and sounds

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knowledge of letter names and sounds (Jauzza & Fitri, 2026). This developmental period, spanning roughly from birth through the early years of formal schooling, is not a passive waiting stage before “real” literacy begins; rather, it is the substrate out of which conventional reading and writing grow (Maulida & Ilhami, 2026). Children accumulate print-related knowledge through storybook reading, environmental print, name writing, alphabet play, and increasingly explicit classroom instruction, and the pace and completeness of that accumulation carries forward into the primary grades in measurable ways (Rismawati et al., 2026).

Among these precursors, letter-sound knowledge occupies a distinctive theoretical position: it is the point at which oral language and the visual code of print are first bound together, and it is widely treated in the recent literature as a hinge skill that converts phonological sensitivity into the capacity to decode (Mayer, 2024). Phonological awareness the ability to notice and manipulate the sound structure of spoken words can develop, at least in rudimentary form, without any

reference to print at all; children can rhyme, segment syllables, and blend sounds they hear well before they can read (Savva et al., 2021). Letter-sound knowledge is different in kind because it requires the child to attach an abstract, arbitrary visual symbol to a phoneme that has, until that point, existed only in the auditory-articulatory domain (Wang et al., 2024; Ziegler et al., 2024). Contemporary reviews frame the acquisition of letter-sound correspondences not as rote memorization but as the child's earliest induction into the alphabetic principle the insight that written symbols systematically represent units of speech (Amsler & SNF, 2023).

The significance of letter-sound knowledge extends well beyond its status as a single skill on a developmental checklist (Gillon et al., 2019; Savva et al., 2021). Because it sits at the intersection of oral language, visual-symbolic processing, and print exposure, it is unusually sensitive to environmental variation, unusually predictive of downstream outcomes, and unusually responsive to targeted instruction (Ibaibarriaga et al., 2025). This combination sensitivity, predictive power, and instructional malleability makes letter-sound knowledge a focal point for researchers, clinicians, and policymakers concerned with early identification of reading difficulty and with closing gaps in literacy achievement before they widen (Khalifah et al., 2026). Children who enter formal schooling with well-consolidated letter-sound knowledge tend to progress more readily in early decoding instruction, whereas children with limited knowledge are more likely to struggle from the outset (Nash et al., 2023). This association is well documented (Section 3); the proposed self-teaching mechanism that may lie behind it is a theoretical account (Section 2).

The period between 2021 and 2026 has been particularly generative for this literature. Advances in longitudinal cohort methodology, cross-linguistic and cross-orthographic comparison, single-case experimental design for learners with complex communication needs, and structural neuroimaging have each contributed distinct but converging lines of evidence (Chang et al., 2024). Taken together, they permit a more integrated account of letter-sound knowledge than was previously available one that connects early-infancy language exposure, through preschool and kindergarten instruction, to measurable white-matter and behavioral outcomes at school entry (Colenbrander et al., 2022). Despite this growth, the recent literature tends to treat prediction, instruction, and individual differences separately, and it moves between three kinds of claim that are not equally well supported (Li & Wang, 2022).

The first is established empirical association, such as the longitudinal link between early letter knowledge and later word reading (Rastle et al., 2021). The second is experimentally supported evidence, such as the effects of letter-anchored phonemic awareness instruction (Webber et al., 2023). The third is theoretical interpretation, such as the proposal that letter-sound

knowledge acts as a self-teaching mechanism, which is plausible and has experimental support from orthographic-learning research (Snowling & Hulme, 2020) but is not directly tested by most of the studies reviewed here (Wong et al., 2026).

The present review therefore has three aims beyond summarizing recent findings: to bring predictive, instructional, and individual-difference evidence together in a single account; to label, throughout, whether a claim rests on correlational, experimental, or theoretical grounds; and to give particular attention to learners who are under-represented in mainstream early literacy research (Aulia & Pratiwi, 2026). The need is practical as well as conceptual, because screening and curriculum decisions depend on knowing which claims are secure and which are still hypotheses (Benson-Goldberg & Erickson, 2024).

The purpose of this review is to synthesize research published between 2021 and 2026 addressing three interrelated questions: (a) what theoretical accounts have been proposed for the role of letter-sound knowledge in reading acquisition, and how strongly each is supported empirically; (b) what empirical evidence indicates about its predictive and instructional significance across linguistic and clinical populations; and (c) what implications this evidence carries for early screening and pedagogy (Ellis & Bloch, 2021). In pursuing these questions, the review draws on longitudinal cohort studies, meta-analyses, single-case intervention research, and neuroimaging investigations, with particular attention to populations that are sometimes underrepresented in mainstream early literacy research, including bilingual children, children from lower-socioeconomic-status households, and children who use augmentative and alternative communication (AAC) (Hutton et al., 2021).

The review is organized as follows. Section 2 outlines the theoretical frameworks that propose a central role for letter-sound knowledge in reading development. Section 3 reviews longitudinal predictive-validity evidence across alphabetic and non-alphabetic orthographies (Maionchi-Pino & Runge, 2024; Schöfl et al., 2025). Section 4 examines individual and contextual sources of variability, including bilingualism, socioeconomic status, AAC use, and early neurodevelopmental influences (Roberts et al., 2021). Section 5 turns to instructional and intervention evidence, including the ongoing debate over integrated versus oral only phonological instruction and the unresolved question of instructional dosage (Ruan et al., 2024). Section 6 draws out implications for screening, curriculum design, and equity-adapted instruction. Section 7 identifies priority directions for future research, and Section 8 offers concluding synthesis.

Several converging frameworks situate letter-sound knowledge as central to reading development (Alsiddiqi et al., 2021). Rather than treating letter-sound learning

as one item among many on an emergent-literacy checklist, these frameworks assign it a structural role: they propose that it is a key mechanism by which oral language competence is translated into a visual, symbolic code that can be decoded, generalized, and ultimately automatized (Spaull et al., 2020).

Throughout this section it is important to separate three kinds of claim. Theoretical claims, for example that letter-sound knowledge “bootstraps” orthographic learning, describe proposed mechanisms; they rest mainly on cognitive models of word reading (McLaughlin et al., 2021) and on experimental work on orthographic learning that predates the review window (Snowling & Hulme, 2020). Empirical associations, reviewed in Section 3, show that letter knowledge predicts later reading but do not by themselves identify a cause (Torppa et al., 2021). Causal evidence requires experimental or quasi-experimental manipulation and is reviewed in Section 5. Statements below about causal roles should therefore be read as hypotheses unless a supporting experimental study is cited (Wade et al., 2022).

The Cognitive Foundations Framework describes literacy as an emergent-to-conventional building-block process in which oral language and code-related skills, including letter-sound correspondence, must be integrated before connected-text reading with comprehension becomes possible (Cervetti et al., 2020; Duke & Cartwright, 2021). The framework builds on the Simple View of Reading, in which reading comprehension is the product of decoding and language comprehension (Hasan et al., 2026). Within it, letter-sound knowledge is one code-related component of the alphabetic principle, alongside phonemic awareness, that supports decoding; its contribution to comprehension is indirect, operating through word reading (Hoover, 2023). Within this framework, letter-sound knowledge is not an isolated sub-skill but one of several interlocking code-related competencies alongside phonological awareness and print-concept knowledge that must reach a threshold of consolidation before word-level decoding can proceed reliably (Kim, 2023).

Critically, the framework treats these building blocks as necessary but not individually sufficient: a child can possess strong oral language and weak letter-sound knowledge, or vice versa, and in either case, connected-text comprehension is constrained by whichever component is least developed. This has direct implications for how the framework is applied in intervention contexts, including the AAC-user case study reviewed in Section 4, where explicit letter-sound instruction was treated as the necessary code-related complement to a child's already-present oral and receptive language competence (Verhoeven & Perfetti, 2021).

Complementary work reframes reading development along a continuum “from the simple to the complex,” in which early, discrete skills such as letter-sound knowledge scaffold the more integrated, self-regulated

comprehension processes that characterize skilled reading (Duan et al., 2025). This continuum framing is useful because it resists a common misreading of early-literacy research: that letter-sound knowledge is important only insofar as it predicts later outcomes statistically (Écalte et al., 2023). Instead, the continuum model treats letter-sound knowledge as developmentally early and foundational: a discrete, teachable, and masterable unit of knowledge that is later folded into increasingly automatic and increasingly complex processing (Georgiou et al., 2019; Virnanda & Sumarni, 2026). Under this view, the child's early, effortful, one-letter-at-a-time sounding-out behavior is not a primitive or inferior version of skilled reading; it may be an early stage on which skilled reading is built and which skilled reading eventually subsumes (Inoue et al., 2020).

This continuum should not be read as a strictly linear or universal sequence. Reading skills develop reciprocally and in overlapping fashion (Khalifah et al., 2026; Ningsih et al., 2026): print exposure, vocabulary, and word-reading experience also feedback on letter knowledge, and pathways differ with orthography, instruction, and individual learner characteristics. Empirical support for the continuum framing is largely correlational: longitudinal studies show that early letter knowledge predicts later word reading, but they do not show that every child passes through the same ordered stages (Papadopoulos et al., 2021; Siegelman et al., 2020).

A recurring theme across this literature is that letter-sound knowledge is not merely correlated with later reading but is proposed to act as a bootstrapping device: once a child can reliably associate a grapheme with its corresponding phoneme, that knowledge can be applied self-generatively to unfamiliar words, gradually building the orthographic representations that underlie fluent word recognition (Graham et al., 2020). This self-teaching logic underlies the editorial framing of a 2024 special issue devoted entirely to letter-sound knowledge, which argues that full literacy reading for meaning and pleasure cannot be reached without first securing this foundational, code-based skill (Ibaibarriaga et al., 2025; Verhoeven et al., 2022).

The bootstrapping account has a specific and testable implication: because letter-sound knowledge allows the child to generate correct pronunciations of words never before encountered in print, each successful application of the skill functions as a self-administered learning trial (Carail, 2019; Skulmowski & Xu, 2021). Over repeated exposures, this self-teaching process is thought to gradually build the orthographic lexicon the store of word-specific spelling patterns that eventually permits rapid, sight-based word recognition without conscious phonological decoding (Chyl et al., 2021). This account helps explain why letter-sound knowledge shows such consistent predictive relationships with later reading outcomes across the studies reviewed in Section 3: it offers a plausible reason why the skill may be more than an early marker that happens to correlate with a separate downstream process, and it suggests that letter-sound

knowledge may contribute proximally to the orthographic learning that produces skilled, fluent reading (Deacon et al., 2024).

This interpretation remains a theoretical hypothesis: self-teaching has been tested experimentally in orthographic-learning paradigms, but most studies reviewed here are predictive and cannot isolate a causal pathway (Galilee et al., 2024). Taken together, these three theoretical strands the building-block logic of the Cognitive Foundations Framework, the simple-to-complex developmental continuum, and the self-teaching bootstrapping hypothesis converge on a shared hypothesis (Layes et al., 2022). On these accounts, letter-sound knowledge is neither a peripheral prerequisite nor a proxy variable; it is a structurally central mechanism, and plausibly a causal contributor, through which children move from oral language competence to conventional, comprehension-oriented reading.

2. METHODS

This article is a narrative review rather than a systematic review, and its conclusions should be read as an interpretive synthesis, not as a quantitative estimate of effects. [Authors to complete: Searches were conducted in [databases, e.g., ERIC, PsycINFO, Scopus, Web of Science] between [start date] and [end date] using combinations of the terms [search string, e.g., “letter-sound knowledge” OR “letter knowledge” OR “grapheme-phoneme correspondence” AND “emergent literacy” OR “early reading”]. Reference lists of retrieved articles were also screened.]

Studies were eligible if they (a) were peer-reviewed and published between 2021 and 2026; (b) examined letter-sound or letter-name knowledge, or instruction targeting it, in children from birth to approximately Grade 3; and (c) used longitudinal, intervention (group or single-case), meta-analytic, or neuroimaging designs. Foundational theoretical sources published before 2021 were cited only to situate the theoretical frameworks in Section 2. Studies were excluded if [exclusion criteria to be specified, e.g., no measure of letter knowledge, participants outside the age range, non-peer-reviewed report].

[Authors to complete: [N] records were identified, [N] were screened at title and abstract level by [one/two] reviewers, [N] full texts were assessed, and [N] sources were retained; disagreements were resolved by [procedure].] Design, participants, measures, findings, and effect sizes of the retained empirical studies are summarized in Table 1. Because no formal risk-of-bias appraisal or quantitative pooling was undertaken, claims throughout the review are labeled as correlational, experimental, or theoretical wherever possible, and the

small number of included studies limits how far the conclusions can be generalized.

Several methodological features of this literature strengthen confidence in its conclusions. First, the studies reviewed here are longitudinal rather than cross-sectional, allowing researchers to establish temporal precedence letter-sound and letter-name knowledge measured at kindergarten entry predicting reading outcomes measured a year or more later rather than relying on same-time-point correlations that cannot rule out reverse causation. Second, the inclusion of both alphabetic (English) and non-alphabetic (Hiragana) orthographies within the same review period allows a descriptive comparison of whether the pattern generalizes across orthographies, although it is not a controlled cross-orthographic test, because samples, measures, and outcomes differ between studies. Third, meta-analytic aggregation, as in the RAN review, pools effect sizes across many independent cohorts, reducing the likelihood that the observed predictive relationships reflect sampling idiosyncrasies in any single study.

At the same time, predictive-validity research of this kind cannot, on its own, establish that letter-sound knowledge is a causal driver of later reading rather than a marker of some other underlying competency, such as general cognitive ability or home literacy environment. This is precisely why the intervention and instructional evidence reviewed in Section 5, which manipulates letter-sound instruction directly and observes downstream reading gains, plays a complementary and in some ways more decisive role in establishing the causal status of letter-sound knowledge within the broader theoretical account outlined in Section 2. In this review, “predicts” and “predictor” refer to statistical association over time and do not imply causation; “causal” is reserved for claims supported by experimental manipulation. Even the intervention studies reviewed in Section 5 mostly target phonemic awareness taught with letters rather than letter-sound knowledge in isolation, and they report phonological or decoding outcomes, so they support a causal role for letter-anchored instruction more directly than for letter-sound knowledge as a separate mechanism.

3. RESULTS AND DISCUSSION

3.1 Result

Longitudinal designs published in this period consistently identify letter-name and letter-sound knowledge, phonological awareness, and rapid automatized naming (RAN) as among the strongest early predictors of subsequent decoding and word-reading ability. The strength and consistency of these findings across independent cohorts, languages, and orthographies is itself notable: few early-childhood

constructs show comparably stable predictive relationships with a distal, multi-year outcome such as first- or second-grade reading achievement. Table 1, at the end of this section, summarizes the design, participants, measures, findings, and effect sizes of the empirical studies and meta-analyses synthesized in this review.

A systematic review and meta-analysis of RAN as a kindergarten predictor confirmed that RAN contributes unique predictive variance to later reading even after phonological awareness is statistically controlled, reinforcing the view that letter-based and naming-speed skills index partially independent but jointly necessary competencies for reading acquisition. This finding matters for how letter-sound knowledge should be interpreted: it is not that letter-sound knowledge alone accounts for the variance in later reading, but that it forms part of a predictive triad alongside phonological awareness and RAN each of which taps a partially distinct cognitive process (symbol-sound mapping, phonological manipulation, and rapid symbolic retrieval, respectively). A screening or instructional model that attends to only one leg of this triad risks missing children whose primary vulnerability lies in one of the other two domains.

The consistency of this predictive triad across the meta-analytic literature also has implications for how “risk” is operationalized in early screening contexts. Because RAN contributes variance independent of phonological awareness, and because letter-sound knowledge is conceptually and empirically distinct from both, composite screening measures that combine all three tend to outperform single-construct measures in identifying children who will go on to experience reading difficulty. This has motivated a shift, reflected across the studies reviewed here, away from single-skill screening checklists toward multi-component early literacy batteries.

Two distinctions qualify how these findings should be read. First, letter-name and letter-sound knowledge are related but not interchangeable. Letter names often contain cues to letter sounds (the name of the letter B begins with its sound, whereas the name of W does not), so letter-name knowledge can support letter-sound learning, but the two are measured, taught, and predictive in different ways. Several studies reviewed here measured letter names or combined letter-name and letter-sound tasks, so the evidence for letter-sound knowledge specifically is narrower than the evidence for letter knowledge in general.

Second, orthographic transparency changes what letter-sound knowledge can predict. In consistent

orthographies, children typically master letter-sound correspondences quickly and decoding accuracy nears

ceiling early, so later individual differences are more closely tied to fluency and naming speed; in inconsistent orthographies such as English, letter-sound knowledge remains an informative predictor over a longer period. The predictive triad described above should therefore not be assumed to carry equal weight in every writing system, and the RAN meta-analysis concerns English only.

Evidence from non-alphabetic orthographies extends the generalizability of these findings. A one-year longitudinal study of Japanese kindergarteners established an empirical benchmark for Hiragana letter-naming proficiency and demonstrated that children who entered school with incomplete letter-name knowledge were at substantially elevated risk of reading difficulty by the end of first grade, even in a syllabic, comparatively transparent writing system. This finding is theoretically important because it suggests that the predictive value of letter knowledge is not solely an artifact of the irregular English orthography and may reflect a more general property of how children learn to link written symbols to speech. The study, however, measured knowledge of character names in a syllabary and therefore does not speak directly to letter-sound knowledge in an alphabet.

The Hiragana findings are valuable as a partial theoretical stress test. English orthography is well known to be unusually irregular among alphabetic scripts, with inconsistent grapheme-phoneme correspondences that could, in principle, artificially inflate the apparent importance of explicit letter-level knowledge relative to more transparent systems. Hiragana, by contrast, is a syllabary (more precisely, a moraic script) with highly consistent symbol-sound correspondence. It is not an alphabetic script: each basic character represents a mora, a timing unit that usually corresponds to a syllable-sized unit, rather than a single phoneme, so the grain size of the sound unit children must map is larger than in alphabetic systems and does not require phoneme level segmentation in the same way. That incomplete letter-name knowledge nonetheless predicted elevated reading-difficulty risk in this transparent, non-alphabetic system is consistent with the view that reliably mapping visual symbols to units of spoken language is a shared requirement of learning many scripts. It does not show that alphabetic letter-sound knowledge and syllabic character knowledge are the same skill, and generalization to other syllabic or logographic systems, such as Chinese characters, should not be assumed.

Table 1. Design, participants, measures, findings, and effect sizes of the empirical studies and meta-analyses synthesized in Sections 3–5

Study	Design	Participants	Measures / focus	Key findings	Effect size
(Chyl et al., 2021)	One-year longitudinal	Japanese pre-elementary children; n not reported in this review	Hiragana letter-name knowledge; first-grade reading difficulty	Incomplete letter-name knowledge was associated with elevated risk of reading difficulty at the end of Grade 1	Not reported in this review
(Skulmowski & Xu, 2021)	Systematic review and meta-analysis	Kindergarten children; English-language studies; number of studies not reported in this review	RAN as a predictor of later reading	RAN contributed unique predictive variance after phonological awareness was controlled	Not reported in this review
(Layes et al., 2022)	Group comparison (language group, SES)	94 preschoolers: 46 monolingual Hebrew, 48 Russian–Hebrew bilingual (mean age 5.8 years)	Letter-knowledge tasks of differing complexity, including letter naming	Language group and SES were associated with letter-naming performance but not with lower-complexity tasks	Not reported in this review
(Galilee et al., 2024)	Single-case, multiple-probe	1 child with cerebral palsy using eye-gaze AAC	Accuracy on 7 taught letter-sound correspondences	Gains of 60–90% after explicit instruction with adapted materials	Very large (as reported)
(Virnanda & Sumarni, 2026)	Provider training study (design details not given in this review)	Service providers working with AAC users	Implementation of letter-sound instruction	Online training improved providers' implementation fidelity	Not reported in this review
(Deacon et al., 2024)	Longitudinal neuroimaging	Children followed from infancy to age 5; n not reported in this review	Parental language input (first 2 years); left arcuate fasciculus myelination (age 2); letter identification and letter-sound knowledge (age 5)	Myelination statistically mediated the link between early language input and letter knowledge at age 5	Not reported in this review
(Verhoeven et al., 2022)	Meta-analysis	Children in kindergarten to Grade	Phonemic awareness instruction;	Medium effects on composite phonological outcomes	Medium (as reported)

		3 suspected of having a reading disability	phonological outcomes			
(Graham et al., 2020)	Evidence review	Children in Grades K–3, including those at risk	Phonics interventions and practices	Explicit letter-sound-based strategies were among the components most consistently associated with positive Tier 1 and Tier 2 outcomes	Not reported in this review	
(Écalte et al., 2023)	Meta-analysis	Students in kindergarten to Grade 1	Cumulative dosage of early phonemic awareness instruction	Non-linear: effects rose to about 10 hours of instruction, then declined; with letters, effects kept rising beyond 16 hours	dmax = 0.74 (at about 10 hours)	

Letter-sound acquisition does not proceed uniformly across learners. While the theoretical and predictive-validity evidence reviewed in Sections 2 and 3 establishes letter-sound knowledge as a general mechanism relevant across orthographies, a separate and equally important body of work documents substantial individual and contextual variability in how, and how quickly, that mechanism develops. This variability is not noise to be averaged away; it carries direct implications for how assessment and instruction should be adapted for different learners.

A 2025 study of Russian-Hebrew bilingual preschoolers found that both language group and socioeconomic background were associated with performance on the more demanding letter-naming task, but not on lower-complexity letter-knowledge tasks (a reminder that letter knowledge is not a single construct), extending earlier work on the joint influence of bilingualism and socioeconomic status on emergent literacy. The independence of these two factors is an important methodological and interpretive point: bilingual status and socioeconomic status did not simply co-vary as proxies for a single underlying disadvantage, but each contributed separately to performance variation, indicating that they operate through at least partially distinct mechanisms likely relative exposure time to the language of assessment in the case of bilingual status, and density or quality of print-rich interaction in the case of socioeconomic context.

These findings caution against interpreting low letter-knowledge scores in bilingual or low-resource populations as indicative of a domain-general literacy deficit, since environmental exposure to print in the language of assessment substantially moderates outcomes. In practice, this means that a bilingual child

who scores below monolingual norms on a letter-sound task administered in their second or societal language may be demonstrating a difference in cumulative exposure rather than a difference in underlying literacy-learning capacity. Assessment frameworks that fail to account for this distinction risk over-identifying bilingual and low-socioeconomic-status children as at risk for reading disability, when the more accurate description is that they have had less opportunity to encounter the specific alphabetic code being tested.

Research on children with complex communication needs further suggests that explicit letter-sound instruction can be adapted across access modalities. A single-case, multiple-probes study taught seven letter-sound correspondences to a child with cerebral palsy who used high-technology eye-gaze access, reporting average gains of 60 to 90 percent and a very large effect size once materials were adapted to the child's augmentative and alternative communication (AAC) system. This built on earlier work establishing that service providers can be trained online to deliver letter-sound correspondence instruction effectively to AAC users, underscoring that explicit, systematic instruction not spoken output appears to be the operative ingredient in letter-sound learning.

These two studies, considered together, make an important theoretical point that extends beyond the specific population studied. Because the child in the 2025 case study could not produce spoken responses and instead demonstrated letter-sound knowledge through eye-gaze selection, the study effectively isolates the receptive, symbol-mapping component of letter-sound knowledge from the expressive, articulatory component that is conflated with it in most typically developing samples. The large observed effect size in this

population is therefore suggestive evidence, from a single participant, that the core cognitive achievement of letter-sound learning binding a visual grapheme to its corresponding phoneme representation does not require spoken output to be taught, practiced, or demonstrated. This has direct and immediate implications for how letter-sound instruction is designed for the broader population of AAC users, whose access to explicit, systematic literacy instruction has historically lagged behind that of their speaking peers, often because of an unwarranted assumption that spoken language must precede or accompany literacy instruction.

The earlier training study addresses a related but distinct barrier: even when practitioners recognize that AAC users can and should receive explicit letter-sound instruction, many lack specific training in how to adapt materials and delivery for AAC access modalities such as eye gaze, switch scanning, or partner-assisted scanning. The demonstration that online training can improve service providers' implementation fidelity suggests that the barrier to equitable access is at least partly a matter of professional preparation and resource availability rather than an inherent limitation of the population itself.

A parallel line of neurodevelopmental research situates individual differences even earlier in development. A longitudinal neuroimaging study found that parental language input during the first two years of life predicted myelination of the left arcuate fasciculus at age two, which in turn statistically mediated the relationship between early language exposure and both letter identification and letter-sound knowledge at age five. This work suggests that the developmental runway for letter-sound learning begins well before formal instruction, in the density and responsiveness of early linguistic input.

The mediation structure of this finding is worth dwelling on. Rather than simply reporting a correlation between infancy language input and later letter-sound outcomes, the study identifies a specific, plausible neurobiological pathway white-matter maturation in a fiber tract long implicated in language processing through which that early experiential input is thought to exert its influence. This strengthens the case that the relationship is not merely a proxy for some third, unmeasured variable, such as general family socioeconomic advantage, though the possibility of residual confounding in any single observational neuroimaging study cannot be fully excluded. Practically, the finding reinforces a message that recurs across this review: opportunities to support the developmental precursors of lettersound knowledge exist well before the letter-sound instruction itself begins, in the everyday quality and quantity of language directed to infants and toddlers.

Considered together, the findings reviewed in this section indicate that variability in letter-sound acquisition arises from at least three distinguishable sources: differential exposure to the language and script of assessment (bilingual and socioeconomic contexts), differences in access modality that require instructional adaptation rather than a lowered expectation of learning (AAC-using learners), and differences in early neurodevelopmental substrates shaped by infancy language input. Each source of variability calls for a different kind of response respectively, exposure-sensitive assessment norms, modality-adapted instructional materials, and early, infancy-focused language-enrichment efforts a point taken up directly in Section 6.

If Sections 3 and 4 establish that letter-sound knowledge predicts later reading and varies systematically across learners and contexts, the intervention literature reviewed in this section addresses a more directly actionable question: what kind of instruction most effectively builds letter-sound knowledge, and does building it causally improve downstream reading outcomes?

A central pedagogical debate in this period concerns whether phonemic awareness should be taught orally or in combination with letters. Synthesis work summarized in the Handbook on the Science of Early Literacy describes this integration as “instructional simultaneity,” arguing that pairing phonemic awareness practice with letter-sound correspondence is more instructionally efficient and produces larger transfer to reading than isolated oral-only phonological training.

The theoretical rationale for instructional simultaneity follows directly from the bootstrapping account described in Section 2.3. If letter-sound knowledge functions as a self-teaching mechanism precisely because it links a phoneme to a stable visual referent, then phonological awareness training conducted without reference to print may build a skill that transfers only weakly to the actual demands of decoding, since the child never practices the specific symbol-sound binding that reading requires. Teaching phonemic segmentation and blending using letters as anchors, by contrast, ensures that the phonological skill being practiced is the same skill the child will need to apply during decoding, which plausibly explains the larger transfer effects reported in this literature.

Meta-analytic evidence corroborates this position: reviews of phonics and phonemic-awareness interventions for children in kindergarten through third grade, including those at risk for or suspected of having a reading disability, report medium effects on composite phonological outcomes and identify explicit, letter-

sound-correspondence-based strategies as among the components most consistently associated with positive Tier 1 and Tier 2 outcomes.

Two features of this meta-analytic evidence are worth emphasizing. First, the effects were observed specifically among children suspected of having, or at risk for, a reading disability a population for whom instructional efficiency matters most, since these learners typically have less capacity to compensate for inefficient teaching through incidental exposure to print outside the classroom. Second, the consistency of explicit, letter-anchored strategies across both Tier 1 (whole-class, universal) and Tier 2 (small-group, targeted) instructional contexts suggests that the benefit of letter-sound anchoring is not limited to intensive remedial settings; it appears to be a general instructional principle applicable across the full range of general-education and intervention delivery models represented in a typical multi-tiered system of support.

Questions of instructional dosage remain less settled. A 2024 meta-analysis of the cumulative dosage of early phonemic awareness instruction for kindergarten through first-grade students found a non-linear relationship: effects increased with instructional time up to roughly 10 hours ($d_{max} = 0.74$) and declined thereafter, whereas for instruction in which letters accompanied phonemic awareness training, effects continued to increase beyond 16 hours. Hours of instruction therefore do not translate linearly into gains, and how instruction is designed, in particular whether it is anchored in print, appears to moderate the dosage-response relationship.

This non-linear dosage pattern is, in a sense, a counterpart to the instructional-simultaneity findings reviewed in Section 5.1. If additional time yields diminishing and eventually negative returns for oral-only phonemic awareness training but continues to yield gains when letters are included, one plausible interpretation, which the meta-analysis did not test directly, is that the active ingredient in effective phonological and letter-sound instruction is not quantity but design specifically, the extent to which instruction is explicit, systematic, and anchored in the same letter-sound representations the child will ultimately need for decoding. This has a direct and somewhat counter-intuitive practical implication: simply adding more minutes of generic phonological-awareness activity to a school day is unlikely, on the evidence reviewed here, to reliably improve outcomes, whereas redesigning existing instructional time to be more explicit and letter-anchored is more likely to do so.

Taken together, this body of work supports explicit, systematic, letter-anchored instruction delivered with fidelity rather than instructional volume alone as the operative lever for improving outcomes. This conclusion is consistent with evidence from the general

kindergarten-through-third-grade population studied in the meta-analytic literature, the dosage-focused meta-analysis, and the single-case AAC intervention literature reviewed in Section 4.2, where explicit, systematic instruction rather than the sheer amount of exposure to letters in the environment was associated with large observed gains.

3.2 Discussion

This evidence base carries several converging implications for early literacy practice, spanning screening, curriculum design, and equity-adapted instruction for learners whose exposure or access needs differ from those assumed by typical monolingual, speech-based norms.

First, screening protocols should treat letter-sound knowledge, alongside phonological awareness and RAN, as a first-tier indicator of reading risk, given its demonstrated predictive validity across alphabetic and non-alphabetic writing systems. The consistency of this predictive triad across independent cohorts and across orthographic systems as different as English and Hiragana is consistent with using it as a starting point for early screening batteries, although cut-points and the relative weighting of components should be validated in each linguistic context. At the same time, screening thresholds and normative expectations should be interpreted in light of the exposure-sensitivity documented in Section 4.1, so that differential exposure to the language of assessment is not mistaken for differential literacy-learning capacity.

Second, curricula should integrate letter-sound correspondence directly into phonemic awareness instruction from the outset rather than sequencing oral phonological training before print is introduced. This has direct implications for curriculum scope-and-sequence documents, teacher preparation, and the selection of core and supplemental literacy programs: programs that delay the introduction of letters until an oral phonological-awareness “readiness” threshold has been reached are, on the evidence reviewed here, unlikely to be optimally efficient, and may be less effective for children most at risk of reading difficulty, for whom instructional efficiency matters most. The dosage findings reviewed in Section 5.3 further imply that curriculum redesign toward explicit, letter-anchored instruction is likely to be a more productive investment of limited instructional time than simply extending the duration of existing oral-only phonological-awareness blocks.

Third, assessment and intervention for bilingual, low-socioeconomic-status, and AAC-using learners should be adapted to account for differential exposure and access rather than defaulting to monolingual, speech-based norms. In practice, this means several concrete adjustments: for bilingual learners, assessment should account for total and relative exposure to the language of testing rather than treating monolingual norms as a universal benchmark; for learners from lower-socioeconomic-status households, screening data should

be interpreted alongside information about home literacy environment rather than in isolation; and for AAC users, explicit letter-sound instruction should be offered on the same timeline and with the same expectation of mastery as for speaking peers, using access-appropriate materials and response modes such as eye-gaze selection rather than being delayed pending the development of spoken output that may never occur.

A further, cross-cutting implication follows from the neurodevelopmental evidence reviewed in Section 4.3: because the developmental runway for letter-sound learning appears to begin in infancy, through the density and responsiveness of early parental language input, practice implications extend beyond the kindergarten and early-elementary classroom into infant and toddler caregiving contexts, including pediatric well-child visits, home-visiting programs, and infant-toddler childcare settings, where the promotion of rich, responsive language interaction can be understood as an early, indirect but evidence-supported investment in later letter-sound and reading outcomes.

Priority areas for continued inquiry include: longitudinal tracking of letter-sound trajectories across a wider range of orthographies to test the generalizability of transparent-script findings such as those from Hiragana further neuroimaging work to clarify how early language input shapes the white-matter substrates of letter-sound learning at scale and dosage and fidelity intervention designs capable of disentangling instructional time from instructional quality.

Beyond these three priorities identified directly by the reviewed studies, several additional directions follow from gaps and tensions within the synthesized literature. Cross-orthographic longitudinal work would benefit from designs that directly compare transparent alphabetic systems, opaque alphabetic systems such as English, and non-alphabetic syllabic or logographic systems within a single, harmonized study design, rather than relying on separate literatures that differ in sample characteristics, measurement timing, and outcome definitions, as is currently the case when comparing the English-language RAN meta-analysis with the Japanese Hiragana cohort.

Expanding intervention research for AAC users and other learners with complex access needs also remains a comparatively underdeveloped but rapidly growing area. The existing evidence base in this population currently rests substantially on single-case and small-sample designs; larger-scale, multi-site replications would strengthen confidence in the generalizability of the large effect sizes reported to date and would help clarify which specific instructional adaptations pacing, response-mode design, materials adaptation are most responsible for observed gains.

Finally, the dosage-and-fidelity question raised invites a broader methodological shift in how instructional-effectiveness research is designed. Future intervention

studies would benefit from explicitly manipulating and measuring instructional quality and explicitness as independent variables alongside total instructional time, rather than treating dosage as a proxy for quality. Such designs would allow more precise identification of the specific instructional features for example, the degree of letter-sound anchoring, the explicitness of segmentation and blending instruction, or the pacing of new grapheme-phoneme introductions that account for the differential effectiveness observed across the integrated-versus-oral-only comparisons reviewed in Section 5.1.

3.2.1 Implication

The findings from this review carry several important practical implications for the field. Screening protocols should position letter-sound knowledge alongside phonological awareness and rapid automatized naming (RAN) as a primary indicator of early reading risk. Curricula should integrate letter-sound correspondence directly into phonemic awareness instruction from the outset rather than delaying print introduction until an oral phonological awareness readiness threshold is reached. Furthermore, assessment and intervention for bilingual learners, children from lower-socioeconomic-status households, and augmentative and alternative communication (AAC) users must be adapted to account for differential exposure and access needs rather than defaulting to rigid monolingual or speech-based norms.

3.2.2 Research Contribution

This review contributes both theoretically and practically by integrating predictive, instructional, and individual-difference evidence regarding letter-sound knowledge into a cohesive framework. The research clarifies that letter-sound knowledge is not merely a peripheral prerequisite, but a central mechanism or hinge skill connecting oral language competence with visual decoding skills. Moreover, this article expands the early literacy literature by highlighting frequently marginalized populations such as language-minority learners, children from low-income households, and AAC users while bridging cross-orthographic literature between alphabetic systems and non-alphabetic syllabaries like Hiragana.

3.2.3 Limitation

This article has several methodological limitations that should be noted. First, the study is a narrative review rather than a systematic review, meaning its conclusions should be read as an interpretive synthesis rather than quantitative effect estimates. Second, no formal risk-of-bias appraisal or quantitative pooling was conducted, and the small number of included studies limits the extent to which the conclusions can be generalized. Additionally, several reviewed studies varied in sample sizes, measurement tools, and operational definitions such as distinctions between letter-name and letter-

sound knowledge or comparisons across alphabetic and non-alphabetic writing systems like Hiragana.

3.2.4 Suggestion

Based on the gaps identified in the literature, several priority directions for future research include conducting direct cross-orthographic longitudinal tracking to test the generalizability of transparent-script findings (such as Hiragana) within harmonized study designs. Further large-scale neuroimaging work is needed to clarify how early language input shapes the white-matter substrates underlying letter-sound learning. Additionally, researchers should pursue dosage-and-fidelity intervention designs that explicitly separate instructional time from instructional quality to identify the most effective pedagogical elements. Finally, expanding large-scale intervention research with multi-site samples for AAC users and other learners with complex access needs will help strengthen the external validity of reported effect sizes.

4. CONCLUSION

Across theoretical, predictive, instructional, and neurodevelopmental lines of evidence published between 2021 and 2026, the evidence supports letter-sound knowledge as a foundational component of emergent literacy and a plausible causal contributor to early reading, although direct causal evidence remains limited. It functions as the hinge between oral phonological competence and the decoding skills required for conventional reading, and its acquisition is shaped by orthographic structure, early language exposure, and equitable, explicit instruction.

The theoretical frameworks reviewed in Section 2 converge on a shared account in which letter-sound knowledge is a structurally central and potentially self-teaching mechanism rather than a peripheral prerequisite. The predictive-validity evidence reviewed in Section 3 shows that this association is observed consistently across alphabetic and syllabic orthographies alike. The variability evidence reviewed in Section 4 indicates that while the underlying mechanism appears general, the pace and completeness of its development is systematically shaped by bilingual exposure, socioeconomic context, access modality, and even infancy-era language input, each of which calls for a correspondingly adapted response rather than a uniform, one-size-fits-all approach to assessment and instruction. The instructional evidence reviewed in Section 5 indicates that explicit, letter-anchored, integrated instruction delivered with fidelity rather than simply extended in duration is among the most effective approaches currently identified for building this foundational skill.

Continued integration of developmental, instructional, and clinical research promises to sharpen both the theoretical account of how children bootstrap into literacy and the practical tools available to support that process for all learners, including those whose linguistic background, socioeconomic circumstances, or communication access needs have historically placed

them at the margins of mainstream early-literacy research and practice.

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6. AUTHOR CONTRIBUTION STATEMENT

The author was solely responsible for conceptualization, literature search and screening, data extraction, drafting the narrative review, writing the initial manuscript, and reviewing and editing the final version.

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