

The Science of Reading

Evidence-Based Practices for Effective Literacy Instruction

One-Page Summary
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The Challenge Reading is a foundational skill for academic and life success, yet only about 31% of U.S. fourth-grade students read at or above the proficient level on the 2024 NAEP. Students who struggle with reading are far more likely to drop out of high school, face unemployment, experience poverty, and enter the justice system. These outcomes highlight an urgent need for evidence-based instruction.

The Science of Reading Solution Decades of research in cognitive science, neuroscience, and education (Dehaene, Seidenberg, Ehri, Share, Wolf, National Reading Panel, and others) converge on one core insight: the alphabetic principle. Spoken words are made of individual phonemes that map predictably to letters and letter combinations (graphemes). Mastering this principle through **explicit, systematic phonics** is the cornerstone of reading acquisition.

Structured Literacy — an explicit, systematic, cumulative, and diagnostic approach — puts the Science of Reading into practice. It is highly effective for all students and essential for disadvantaged students, English-language learners, and those with dyslexia.

Key Recommendations

- Begin rich oral language, phonological awareness, and playful letter-sound activities in preschool (ages 3–4).
- Teach concept vocabulary using a structured **four-stage sequence**: Meaning → Letter-Sound Association → Isolation → Context.
- Deliver explicit, systematic phonics instruction with a clear scope and sequence, decodable texts, and built-in review.
- Balance code instruction with daily rich read-alouds that build vocabulary and expose students to complex sentence structures.
- Use multisensory techniques (tracing, letter tiles, segmenting boxes, mouth positions, mnemonics).
- Incorporate well-designed technology for adaptive practice, immediate feedback, and increased reading volume while maintaining strong teacher oversight.
- Provide ongoing professional development for teachers and monitor progress with frequent, targeted assessments.

Proven Results States that have implemented comprehensive Science of Reading reforms have seen substantial gains. Mississippi, for example, rose from 49th in the nation to near the national average (top 10) on fourth-grade NAEP reading after adopting systematic phonics and Structured Literacy practices.

Conclusion By combining explicit phonics, rich concept vocabulary, extensive reading, and supportive technology, we can dramatically improve literacy outcomes and give every child the opportunity to become a confident, fluent reader.

The Science of Reading: Evidence-Based Practices for Effective Literacy Instruction

White Paper

Dr. Stephanie Merkley

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Executive Summary

Reading is a foundational skill for academic success, yet only about 31% of U.S. fourth-grade students read at or above the proficient level on the 2024 NAEP. Decades of research from cognitive science, neuroscience, and education converge on the alphabetic principle and the need for explicit, systematic phonics. This white paper synthesizes key findings from leading experts and offers practical recommendations, including a four-stage concept vocabulary sequence and the effective use of well-designed technology. Structured Literacy benefits all students and is essential for disadvantaged students, English-language learners, and those with dyslexia.

Introduction

Reading is a foundational skill for academic success. As highlighted by the 2024 NAEP results—where only about 31% of fourth-grade students read proficiently—many students continue to struggle without explicit, systematic instruction grounded in cognitive science. Decades of research from experts including Stanislas Dehaene, Mark Seidenberg, Linnea Ehri, Timothy Shanahan, David Share, Maryanne Wolf, Susan Brady, and organizations such as the International Dyslexia Association (IDA) and The Reading League converge on one core insight: the alphabetic principle—spoken words are composed of individual phonemes that map predictably to graphemes. Mastering this principle through explicit, systematic phonics is the cornerstone of reading acquisition.

This white paper reflects my synthesis of extensive research. It examines how the brain learns to read, dyslexia, the Reading Wars, Structured Literacy versus Whole Language approaches, when to begin instruction, best practices, the self-teaching phase, and the role of technology. My key recommendations prioritize explicit phonics, concept vocabulary taught in stages, decodable texts, extensive reading, and well-designed digital tools. These practices benefit all students and are essential for those with dyslexia or at risk.

The “Science of Reading” draws from interdisciplinary research on how the brain learns to read. As Stanislas Dehaene explains, reading is not a complete change of brain networks but a “recycling” of existing spoken-language areas. When we read, visual input enters the occipital pole, activates the visual word form area (VWFA), and connects to areas for pronunciation and meaning (Dehaene, 2009; various lectures including “How the Brain Learns to Read”). “We read with our eyes,” notes Mark Seidenberg, “but the starting point for reading is speech” (Seidenberg, 2017). The brain reuses the already-developed spoken-language network by creating an interface between print and sound.

Reading proficiency is critically important. Students who struggle with reading are far more likely to drop out of high school, face unemployment, experience poverty, and become involved in the justice system. Poor reading skills in third grade predict future academic and life outcomes with alarming accuracy. These statistics highlight an urgent need to improve reading education through evidence-based methods rather than approaches that have failed generations of students.

The alphabetic principle—the insight that spoken words are made of phonemes (individual sounds) and letters or letter combinations (graphemes) map to those sounds in a predictable way—is the key to cracking the code. Without it, reading remains guesswork. Explicit, systematic teaching of this principle produces stronger outcomes in decoding, spelling, and comprehension. Dehaene describes learning as adjusting mental-model parameters, minimizing errors, and building hierarchical models—processes that explicit phonics leverages perfectly.

Disadvantaged students, English-language learners, and those with dyslexia benefit most from structured approaches. A rich spoken-language environment is crucial: “A richer spoken language environment leads to greater knowledge of spoken language which then facilitates learning to read” (Seidenberg, n.d.).

How We Learn to Read

Reading builds on spoken language. The brain reuses existing networks for phonology, lexicon, syntax, and semantics, creating a new visual interface. Dehaene describes this as “neuronal recycling”: the visual word form area develops rapidly once children receive systematic input linking letters to sounds.

Learning follows Dehaene’s core principles of how the brain acquires new skills. These principles apply directly to learning to read:

Dehaene’s Four Core Principles of Brain Learning

Principle	Description	Application to Reading Instruction
Adjusting mental models	The brain constantly refines its internal model of how print relates to speech	Explicit phonics provides clear, consistent data for accurate mapping
Minimizing errors	Every incorrect guess supplies valuable feedback	Immediate corrective feedback during blending accelerates learning
Exploring possibilities	Young children test different combinations of letters and sounds	Structured word-building activities and decodable texts support discovery
Optimizing reward function	The brain is motivated by success and progress	Games, frequent small successes, and progress tracking strengthen learning

These principles explain why explicit, systematic phonics instruction is so effective. Rather than relying on guessing from pictures or context, children build strong, accurate neural connections through clear instruction, timely feedback, and repeated successful practice.

Both Mark Seidenberg and Stanislas Dehaene describe the transition to understanding the alphabetic principle as a pivotal, transformative phase in learning to read. This is the critical insight that letters and letter combinations (graphemes) systematically represent the sounds (phonemes) of spoken words. It moves children from treating print as arbitrary visual patterns or guessing whole words to actively decoding and encoding using letter-sound mappings. Once grasped, this understanding enables self-teaching, where children can independently figure out new words rather than relying on memorization or context cues (Share, 1995).

Dehaene characterizes this shift as a “true mental revolution.” He explains that speech must be broken down into phonemes and linked to print through explicit teaching of grapheme-phoneme correspondences. This insight radically reorganizes the brain: it strengthens the visual word form area and creates efficient neuronal hierarchies that quickly convert letters into sounds. Seidenberg views it as a “key intellectual insight” or “getting the alphabetic idea” — the gateway from pre-alphabetic guessing to systematic sound-based decoding. He emphasizes that while the initial breakthrough is important, it opens the door to gradual statistical learning of larger orthographic patterns through extensive reading. Both researchers agree this transition does not occur spontaneously for most children and requires explicit, systematic instruction. When supported well, it typically occurs during early reading instruction, often by the end of first grade, after which reading becomes increasingly efficient and self-sustaining.

Vocabulary and concept knowledge form the foundation of reading. Children first link print to already-known spoken concept words. They then learn to break those words into sound parts represented by letters and eventually move from reading in isolation to reading in context.

Four-Stage Concept Vocabulary Sequence

Stage	Name	Goal
1	Meaning	Build deep conceptual understanding and strong oral vocabulary so the word has rich meaning before children see it in print.
2	Letter-Sound to Symbol Association	Link spoken words and sounds to their written form (letters/graphemes), laying the foundation for the alphabetic principle.
3	Read and Write in Isolation	Develop automatic recognition of the word on its own, without pictures or context, strengthening orthographic mapping.
4	Read and Write in Context	Apply the word fluently in sentences and longer texts to build comprehension, fluency, and expressive writing.

Fluency and comprehension emerge from extensive reading. Most orthographic knowledge develops implicitly through massive amounts of practice. Skilled reading becomes automatic—like a reflex—through enormous reading experience that fine-tunes neural machinery (Seidenberg, “Some Tenets for Teachers”). “Repeated exposure to vocabulary in many contexts aids word learning” (LINCS, 2001).

Understanding Dyslexia

Dyslexia is a specific learning disability that is neurobiological in origin. It is characterized by difficulties in word reading and/or spelling involving accuracy, speed, or both. These difficulties typically result from deficits in the phonological component of language (though phonological and morphological processing weaknesses are common but not universal). Brain-imaging studies consistently show reduced specialization of the visual word form area (VWFA) and disorganized or weaker connectivity between visual and language regions.

Dyslexic readers often show “noisy processing in the phonological system,” treating similar patterns as “too different,” which requires relearning material multiple times (Seidenberg, 2017). Maryanne Wolf identifies core subtypes based on rapid automatized naming (RAN) deficits: slow naming speed (fluency issues), core phonemic awareness deficits, or both (double deficit). Dehaene describes additional visual subtypes, such as letter-position dyslexia (helped by finger-tracking or increased spacing) and attentional dyslexia (helped by word masks or visual isolation).

Some students who appear to read well early on later struggle significantly, but they may not have dyslexia. These children are often quick memorizers who relied on visual whole-word recognition rather than learning the alphabetic principle. They can handle simple, high-frequency words but falter with longer or unfamiliar words because they never developed strong decoding skills or self-teaching ability. Their difficulties stem primarily from inadequate instruction rather than a neurobiological phonological deficit.

Explicit, systematic, cumulative, and multisensory reading instruction is essential for students with dyslexia and for many others who struggle for instructional or environmental reasons.

Reading Wars

The debate over how to teach reading—often called the “Reading Wars”—dates back to the 1800s. Horace Mann promoted a “whole-word” or meaning-first approach. Phonics-based methods dominated earlier but lost ground in the mid-20th century to “whole language,” which emphasized authentic texts, context cues, pictures, and guessing over explicit decoding. The three-cueing system (meaning, syntax, visual) treated graphophonic cues as a last resort. This was considered a faster path to reading and was preferred by many because it focused on the enjoyment of text.

By the 1990s, “balanced literacy” emerged as a compromise but often retained heavy reliance on context and minimal systematic phonics. In response to ongoing controversy and disappointing reading outcomes, Congress commissioned the 2000 National Reading Panel. This independent, bipartisan panel of leading researchers reviewed more than 100,000 studies and conducted a rigorous meta-analysis of 38 high-quality experimental studies. The Panel concluded that systematic phonics instruction produces significant benefits in word reading, spelling, and comprehension, with an overall effect size of approximately 0.41 compared to little or no phonics.

Benefits were strongest when started early (kindergarten or first grade) and combined with instruction in phonemic awareness, fluency, vocabulary, and comprehension. The Panel found little evidence supporting whole-language or meaning-first approaches as primary methods. Its findings remain one of the most authoritative and widely cited bodies of evidence in reading science.

Despite this evidence, implementation remained inconsistent. NAEP proficiency rates stayed low under whole-language and balanced-literacy approaches. However, states that adopted explicit phonics have seen substantial gains. Mississippi, for instance, climbed from 49th in the nation to 9th on fourth-grade NAEP reading after comprehensive Science of Reading reforms.

Structured Literacy vs Whole Language

Structured Literacy is built directly on the findings of the 2000 National Reading Panel. It is explicit, systematic, cumulative, and diagnostic. In contrast, Whole Language (and many balanced-literacy implementations) takes a very different approach.

Comparison of the Two Approaches:

Aspect	Structured Literacy	Whole Language (and many Balanced Literacy approaches)
Core Philosophy	Reading is a learned skill requiring explicit teaching of the alphabetic principle	Reading emerges naturally through exposure to authentic literature and rich language
Phonics Instruction	Explicit, systematic, and cumulative with a planned scope and sequence	Incidental or minimal; taught only “as needed”
Decoding Approach	Strong emphasis on phoneme-grapheme correspondences and blending	Heavy reliance on three-cueing strategies (meaning, syntax, partial visual cues)
Reading Materials	Decodable readers that match taught patterns	Leveled readers relying on pictures, context, and sentence predictability
Skill Integration	Combines decoding, encoding (spelling), handwriting, and multisensory techniques	Prioritizes meaning and whole-text experiences
Assessment	Ongoing diagnostic assessment with immediate corrective feedback	Less systematic diagnostic focus
Outcomes for At-Risk Students	Strong results for disadvantaged students, English learners, and students with dyslexia	Weaker long-term outcomes, especially as text complexity increases

Decodable readers are texts carefully written so that most words are composed only of the phonics patterns students have already been taught. As students master new skills, the texts gradually increase in complexity. These readers allow children to practice active decoding successfully and build automaticity without being overwhelmed by unfamiliar spelling patterns.

In contrast, leveled readers rely heavily on pictures, predictable sentence patterns, repeated high-frequency words, and context cues to encourage guessing. While they may seem easier at first, they often introduce uncontrolled spelling patterns too early. Students can memorize many simple words, but they struggle as texts become more complex because there is too much to memorize without a strong understanding of the alphabetic code. Structured Literacy, supported by decodable readers, prevents this problem by building strong self-teaching ability.

When to Start Reading Instruction

There is no critical age for learning to read—adults can learn successfully—but early exposure produces the best results. Dehaene’s research highlights the remarkable plasticity of the young brain. The visual word form area (VWFA) is highly responsive to structured input during the preschool years, allowing even 3- and 4-year-olds to begin building the neural foundations of the alphabetic principle. Studies show that targeted, short game-based sessions focused on letter-sound correspondences are effective at initiating development of this specialized brain region (e.g., Roberts, 2018; Peña et al., 2024). Preschoolers (ages 3–4) can therefore benefit greatly from playful phonological awareness activities, rich concept vocabulary development, and early letter-sound links. Full systematic phonics instruction typically begins in kindergarten, with most children becoming fluent by the end of first grade when given explicit teaching.

Oral vocabulary development starting in early preschool is especially powerful. Children from lower-income families and English-language learners (ELL) often enter school with smaller vocabularies and less familiarity with English sounds and structures. Studies show these gaps significantly predict later reading difficulties. Rich, repeated exposure to spoken language in preschool builds the conceptual and phonological foundation needed for reading. Early vocabulary intervention helps close achievement gaps before formal reading instruction begins and prevents many children from being misidentified as having reading disabilities when the primary issue is limited language exposure.

Best Practices for Teaching Reading

Dehaene’s four pillars—attention, active engagement, feedback, and consolidation/automatization—guide these practices:

- Follow a clear scope and sequence with built-in review. A logical progression from simple to complex skills, with regular spiral review, ensures children master each step before advancing and reduces confusion (e.g., begin with CVC words, progress to digraphs, vowel teams, and multisyllabic strategies.)
- Prioritize explicit, systematic phonics and the alphabetic principle. Teach letter-sound correspondences directly using real vocabulary words rather than waiting for discovery. Model blending (e.g., /s/ /a/ /t/ → “sat”) and provide guided practice so children understand the predictable code.

- Use decodable texts initially. Provide books composed mostly of words children can decode with the patterns they have been taught. This builds confidence and prevents reliance on guessing.
- Incorporate ongoing assessment and responsive teaching. Quick, regular checks (such as nonsense-word fluency or oral reading) allow teachers to spot gaps immediately and reteach targeted skills right away.
- Balance code instruction with daily rich read-alouds and concept vocabulary building. Alternate between focused decoding practice and teacher read-alouds of complex texts. These read-alouds develop rich spoken vocabulary through themed concept words, conversations, and stories, while simultaneously exposing students to more complex sentence structures and advanced syntax.
- Use multisensory techniques: handwriting, mouth positions, mnemonics, letter tiles, and segmenting boxes. Pair letter sounds with physical actions such as tracing, feeling mouth positions, or using picture mnemonics to engage multiple brain pathways and strengthen memory. Letter tiles and segmenting boxes are especially useful for phoneme segmentation and blending practice.
- Keep sessions short and frequent for young learners (10–15 minutes). Brief, repeated practice matches young children’s attention spans, prevents fatigue, and builds strong neural connections through consistent exposure.
- Differentiate for diverse needs, including dyslexia supports. Provide extra repetitions, modified text spacing, word masks, or intensive small-group tutoring so every child receives the intensity and support required.
- Emphasize extensive reading for fluency and implicit learning. Offer repeated oral reading, choral reading, theater activities, and large volumes of decodable and authentic texts so children develop automaticity and absorb orthographic patterns implicitly.

The Self-Teaching Phase: Becoming an Independent Reader

Once children have mastered the foundational building blocks—phoneme-grapheme correspondences, blending, and a solid base of concept vocabulary—they enter the self-teaching phase. Mark Seidenberg emphasizes that after the initial explicit instruction, too much direct teaching can actually hinder progress by taking time away from the massive amounts of actual reading needed for orthographic mapping and fluency.

In this phase, children no longer decode every word sound-by-sound. Instead, they “know” words at a deeper level because the letters and sounds are tightly bonded in memory through orthographic mapping. This is not rote visual memorization but a rich, connected understanding where the spelling, pronunciation, and meaning are stored together. When they encounter a new word, they decode it efficiently but also draw on their growing knowledge of similar words, word families, syllables, and morphemes (e.g., recognizing “tion” as /ʃən/ or the “tle” chunk in words like *little* and *bottle*). They use larger “chunks” rather than individual phonemes. “The use of the artificial letter

sounds drops away as the child transitions to associating spelling patterns... with their actual pronunciations” (Seidenberg, 2024).

At this stage, learning becomes increasingly implicit. Children absorb patterns through volume of reading, refining their mental models with far less explicit instruction. Seidenberg notes that most orthographic knowledge develops through naturalistic reading and writing experiences. Some targeted instruction on advanced patterns (prefixes, suffixes, multisyllabic strategies) remains helpful, but the primary driver is extensive, meaningful reading. This self-teaching process is how children move from labored decoding to fluent, automatic reading.

The Role of Technology and Computer Systems in Teaching Reading

Well-designed computer-based reading programs offer powerful benefits when grounded in cognitive neuroscience and Structured Literacy principles. These systems (such as the Acellus Learning System) provide adaptive pacing that adjusts difficulty in real time to each child’s performance, ensuring no one is left behind or bored. Immediate, corrective feedback helps students minimize errors and strengthen neural pathways far more efficiently than traditional paper-based practice. They can offer personalized decodable texts and stories using the child’s mastered words, dramatically increasing reading volume and motivation. For fluency, audio models, repeated reading features, and progress tracking help students practice until reading sounds natural. Dyslexia supports such as adjustable letter spacing, word masks, highlighted text, and modified fonts make instruction accessible to every learner. Progress dashboards give parents and teachers real-time data for early intervention. Overall, high-quality computer-based programs scale explicit, systematic instruction, maintain engagement through gamification, and make the Science of Reading engaging, efficient, and widely accessible.

Technology is particularly effective at supporting concept vocabulary development and sight word learning. In a well-designed preschool reading course, concept words can be taught through a structured, four-stage sequence that builds strong foundations for literacy while integrating selected high-frequency sight words.

Technology Implementation of the Four-Stage Concept Vocabulary Sequence

Stage	Goal	How Technology Supports This Stage
1	Meaning	Picture-to-picture matching while saying words; word-to-picture matching; word-to-word matching
2	Letter-Sound to Symbol Association	Animated letter tracing with audio; explicit teaching of single letters and digraphs with mnemonics; letter-sound matching; filling in missing sounds (initial, medial, final)
3	Read and Write in Isolation	Trace and write words; drag-and-drop letter activities (word puzzles); build words with letter cubes after choosing pictures
4	Read and Write in Context	Read and create sentences using concept words and sight words; options to illustrate sentences

This interactive, multimedia approach allows young children to progress through the stages at their own pace with immediate feedback, making the four-stage sequence highly effective even in preschool. This method aligns with the Science of Reading by combining rich oral language development with explicit instruction, orthographic mapping, and meaningful practice, giving preschoolers the vocabulary and decoding foundations they need to become confident, successful readers.

This course can complement concept words with short sight-word videos featuring cute animations. The repeated auditory exposure in meaningful visual contexts supports implicit memorization, reinforcing both phonics and vocabulary development simultaneously.

Sight words are high-frequency words that appear repeatedly in written text (e.g., *the, of, said, to, you, was, have*). Many of these words are phonetically irregular, meaning they do not fully follow standard letter-sound rules. Unlike concept words, sight words often lack clear picture associations because they are abstract or serve grammatical functions rather than naming tangible objects or ideas. This makes them even more difficult to read and understand. However, research on orthographic mapping by Linnea Ehri and others has shown that teaching sight words by explicitly linking their graphemes to phonemes is significantly more effective than rote visual memorization. This aligns with Dehaene's findings that the brain processes even irregular words through letter-sound connections rather than pure visual memorization (Dehaene, 2009).

Note on implementation: Well-designed programs can scale explicit instruction effectively. However, technology works best as a powerful complement to high-quality teacher instruction rather than a replacement. Over-reliance on screens can sometimes reduce human interaction, deep discussion, or transfer to print materials. Effectiveness depends on strong alignment with Structured Literacy principles, teacher training, and balanced implementation.

Conclusion and Recommendations

The Science of Reading, delivered through Structured Literacy, offers a proven path. By recycling the brain's language networks through explicit phonics, rich concept vocabulary taught in meaningful stages, extensive reading, and well-designed technology, we enable self-teaching and give every child the gift of literacy.

Practical Recommendations

- Adopt a Structured Literacy curriculum that integrates systematic phonics with a four-stage concept-word sequence (Meaning → Letter-Sound Association → Isolation → Context) to build strong vocabulary foundations and the alphabetic principle from the start.
- Prioritize decodable readers in the early stages so children can actively practice decoding with words that match their current phonics knowledge, avoiding guessing and building self-teaching ability.
- Begin rich oral language and concept vocabulary development in preschool (ages 3–4), using playful activities to build spoken language, conceptual knowledge, and early letter-sound correspondences before formal reading instruction begins.

- Teach high-frequency sight words through orthographic mapping—explicitly linking graphemes to phonemes—rather than whole-word visual memorization, supported by repeated contextual exposure and animated videos.
- Incorporate well-designed technology tools (such as the Acellus Learning System) that deliver adaptive practice, immediate feedback, the four-stage concept-word sequence, and personalized reading materials to increase engagement and instructional intensity—while maintaining strong teacher oversight.
- Provide ongoing professional development for teachers on the Science of Reading, brain-based learning principles, and Structured Literacy (e.g., through The Reading League or LETRS programs) so they can implement these approaches with fidelity.
- Monitor student progress frequently using simple assessments of phonemic awareness, decoding, and word recognition, and intervene early with targeted, intensive support when needed.
- Study and adapt proven state models, such as Mississippi’s Literacy-Based Promotion Act, with a strong focus on equity for underserved populations.

I believe implementing these practices can dramatically improve literacy outcomes and give every child the opportunity to become a confident, fluent reader.

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This white paper is based on the author's synthesis of the research literature together with practical ideas for implementing effective reading instruction through digital technology.