Unpacking the science of reading research

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Contents

Glossary

alphabetic principle   The understanding that letters represent the sounds in words

construct   A label for a behaviour or group of behaviours in a particular domain that are used by researchers to improve understanding of that domain. Constructs are demonstrated in observable behaviours that can be described and measured by observing what students say, do or make.

domain   An area of learning or cognition that is evidenced by constructs, e.g. reading is a domain made up of the Big 6 constructs.

expressive communication   Verbal and non-verbal messages to a person that express feelings, wants, likes, dislikes, comments and intents.

grammar   The system and structures of a language, usually consisting of syntax and morphology and sometimes also phonology and semantics.

grapheme   Written or printed letter/s representing phonemes.

grapheme–phoneme correspondences (GPCs)   The relationship between the 26 graphemes in English and the 44 phonemes that they can be organised to represent.

morpheme   A meaningful unit of language e.g. 'in' and 'come' are morphemes that together make 'income'.

morphology   The study of morphemes, the smallest meaningful units of a language.

non-words   Words that follow English spelling patterns but have no corresponding meaning in English.

orthographic mapping   The process of decoding graphemes and mapping them to phonemes, morphemes and syntax when reading to generate meaning.

phoneme   The smallest unit of sound in spoken language.

phoneme blending   Orally joining phonemes together to say a word.

phoneme isolation   The ability to a single out a phoneme from the rest of a word.

phoneme manipulation   Deleting, inserting, exchanging and swapping phonemes in spoken words to make new words.

phoneme segmentation   Breaking spoken words into their constituent phonemes.

phonemic awareness   The ability to identify, produce and manipulate the smallest units of sound in language: phonemes.

phonics	The relationship between phonemes and graphemes that supports understanding of the alphabetic principle, as well as an instructional approach to teach reading and spelling.
phonological awareness	The overarching ability to identify, produce and manipulate all different units of sound in a given language word-level, to syllable, to phoneme.
phonology	The study of how languages organise their sounds or constituent parts; also, the sound system of a particular language.
pragmatics	Understanding and using language to communicate in social contexts.
prosodic texts	Texts that demonstrate pleasing patterns of rhythm and sound through stress and intonation.
prosody	Applying the stresses and intonations of spoken language to the reading of texts in a way that enhances meaning through the use of expression, characterisation and through attention to punctuation.
receptive communication	The process of receiving and understanding verbal and non-verbal messages from a person.
semantics	Making sense of language through analysis, from word meanings to whole texts and discourse, and the relations between them.
structured literacy	Systematic and explicit teaching of decoding skills by focusing on phonology, alphabetic principle, syllables, morphology, syntax and semantics.
syntactic knowledge	Knowledge of syntax.
syntax	The arrangement of words and phrases to create well-formed sentences including the set of rules of a language.

Introduction

The benefits of learning to read proficiently include academic success, access to graduate-level education, increased contribution to economic growth, and importantly the ability to fully participate in society (Gross et al., 2009). It is not surprising then that a major goal for education systems across the globe is to teach students to read proficiently.

Reading is defined by the International Literacy Association (2023) as, 'the process of simultaneously extracting and constructing meaning through interaction and involvement with written language.' It is a complex and multifaceted process, which does not come naturally to humans. It requires a person to decipher texts while simultaneously making meaning. For comprehension to occur, learners need to be taught the knowledge, skills and strategies that support decoding and to connect what they read to their prior knowledge. Teachers and researchers look to advancing evidence for how to best facilitate the processes of decoding and meaning-making associated with learning to read.

The science of reading (sometimes referred to as SoR) is a term used for the body of evidence that encompasses multidisciplinary research from education, cognitive psychology, linguistics and neuroscience. This evidence points to 6 key constructs that contribute to proficient reading: oral language, phonological awareness including phonemic awareness, phonics, fluency, vocabulary and reading comprehension. Research around these constructs provides researchers and teachers with an evidence base of the knowledge, skills and strategies involved in competent reading and describes how reading develops in both typical and atypical readers. Learning to read is impacted by genetic, cognitive and psychological factors. As researchers build the body of research that makes up the science of reading, teachers can draw on it to shape their pedagogical practices so that students can move smoothly from learning to read to reading to learn.

This paper synthesises evidence reviews conducted by Australian Council of Education (ACER) researchers that unpack the science of reading. The aim of this synthesis is to demonstrate the impact that research in reading development is having on current ACER research and products. Most importantly, it supports understanding of the importance of embracing the complexity and nuance of reading research and the need for improved efforts to clearly communicate evolving research evidence. ACER draws on the evolving evidence of the science of reading to inform our approach to developing assessments and resources for teachers. We also refer to this evidence to describe where children are in their reading journey. This means a student's progress through each of the constructs described in this paper can be tracked and used to inform teaching and learning.

What is the science of reading?

The body of evidence that makes up the science of reading should inform teaching from the earliest opportunity because students with low levels of language and literacy in the early years of schooling are unlikely to 'catch up' (Ferrer et al., 2015; Snow, 2021).

Drawn from major inquiries into reading and more recent research, the following 6 constructs have been promoted as the 'Big 6' in early reading, including by the Australian Primary Principals Association (Dempster et al., 2012) and in accredited initial teacher education courses (AITSL, 2020):

- oral language

- vocabulary

- phonemic awareness (and phonological awareness)

- phonics

- fluency

- reading comprehension.

The Big 6 is a well-accepted and useful set of constructs. This paper unpacks the evidence base and implications for teaching of each of these constructs while recognising that they are interrelated and have different roles at different times in the development of early reading skills. Some, such as phonemic awareness and phonics are constrained skills, which are largely mastered by the time a student starts reading independently for meaning (Paris, 2005). Others, such as oral language, vocabulary and comprehension, require deep conceptual development and are unconstrained in that they can continue to develop across the student's life (Turner et al., 2018).

The glossary on page 4 defines formal terms from the science of reading research used throughout this paper.

Oral language

Oral language functions as the foundation for effective communication, enabling people to express themselves in a way that ensures mutual understanding. It is considered the foundation for literacy, as speaking and listening, reading, and writing all rely on oral language development (Snow, 2021). The reciprocal relationship between oral language and literacy means oral language improves reading and writing, and reading and writing improves oral language (Castles et al., 2018). The number and variety of words a student hears in their early years underpins their primary literacy learning and later reading achievement (IOM & NRC, 2015; Konza, 2014). Strong early language skills and effective communication are associated with students' general learning ability and success in life (Munro, 2011). Variation in students' oral language development has been linked to language delays, differences in reading comprehension (Nation & Snowling, 2004) and early behaviour problems (Plomin et al., 2002; Slot et al., 2020). Further, students with limited oral language skills during the early years of formal schooling performed the lowest in reading, literacy and vocabulary 7 years on (Walker et al., 1994). The importance of oral language in reading development is acknowledged in major reports into teaching reading (National Reading Panel, 2000; Rose, 2006; Rowe, 2005) and recent research has confirmed the case for oral language to be included as a core construct of the science of reading (Konza, 2014).

Oral language development is complex and can be thought of as multidimensional, involving a range of language structures. Defining these language structures is difficult and there is limited consensus among educational researchers about which structures underpin oral language. Oral language is closely linked to semantic understanding, vocabulary, morphology and phonemic awareness. The language structures listed in Table 1 represent those discussed in the key reading reports (Konza, 2014; National Reading Panel, 2000; Rose, 2006). As shown, these are typically classified into three overarching components (Paul et al., 2017): form, content and use.

Table 1 Relationships between oral language subconstructs and other reading constructs

Oral language sub-constructs	Science of reading constructs
Form	phonology
	syntax
	morphology
Content	vocabulary
	semantics
Use	pragmatics

Understanding grammar, particularly complex sentence structures, helps students comprehend stories read to them and those they subsequently read themselves.

> … students learn the grammatical rules or syntax of language unconsciously as they become familiar with how to correctly combine words into phrases and sentences… (Konza, 2014, p. 156)

Finally, it is important to note that oral language is a skill that continues to develop across a person's lifespan.

What does research say about effective teaching of oral language?

While a significant portion of educational research on teaching oral language skills focuses on preschool-aged learners, it is crucial to recognise that if a goal of formal schooling is to consistently enhance students' oral language abilities, then these findings are relevant and applicable across all levels of education. Strong oral language skills are the foundation for effective expressive and receptive communication.

Language role models

Students learn the structures of language through oral language, which is nurtured from birth and impacted by the quality of interactions they have with significant people in their life (Brushe et al., 2021). Researchers stress that to expand vocabulary, as well as children's understanding and use of various language structures, they need to interact with more proficient language users (Hart & Risley, 1995; Morrow & Rand, 1991).

Dialogic practices

Teachers contribute to students' oral language development and communication skills through day-to-day classroom interactions, modelling complex syntax and using sophisticated vocabulary. This is achieved with receptive and expressive dialogical practices that encourage students to interact using gestures, words, phrases and back-and-forth exchanges (Beitchman & Brownlie, 2010; Morgan et al., 2015; Pianta, 2006; Slot et al., 2020).

Conversation about texts

Reading to students and actively engaging them in conversations around quality texts and literature that have the potential to introduce new vocabulary, colloquial language, and more complex syntax, supports their oral language development. The goal is to encourage analytic talk. Texts can be revisited to review and consolidate learning (Adlof, 2019; Beck et al., 2013; Grifenhagen et al., 2017).

Ultimately, for such pedagogical strategies to be effective, teachers need to understand oral language development and how it relates to, and impacts reading development (Konza, 2014).

Vocabulary

Vocabulary is all the words a person understands, and it is clearly linked to oral language development. A rich vocabulary is essential in developing reading comprehension from the earliest point in learning to read, as readers must understand the meaning of between 93–97% of words in a text to accurately interpret its meaning (Allington, 2011; Burns, 2024; Konza, 2011). Students with richer vocabularies read words more accurately (Snow et al., 2014). A deep vocabulary along with good comprehension skills correlates highly with success in later years of schooling when students read more complex texts (National Early Literacy Panel, 2008; Senechal & LeFevre, 2002).

A deep vocabulary refers to the extent of a reader's associations between different words, their understanding of the flexible ways words can be used in different contexts, and their understanding about how context affects word meanings (Beck et al., 2013; Biemiller, 1999; Graves, 2006). Exposure to rich language environments (both oral and written language) contributes to a more abundant vocabulary and to more comprehensive understanding of ideas, which may in turn lead to more successful experiences of reading (Cunningham & Stanovich, 1998). Conversely, students with limited vocabularies are caught in a diminished trajectory; their insufficient vocabulary consequently limits their vocabulary growth and capacity to read a range of texts. However, there is more to vocabulary than knowledge of a wide range of words; students must also know about how those words are 'put together'.

Morphology is the study of morphemes, the smallest meaningful units of a language. These units can be joined together to create specific word meanings and the study of this process supports vocabulary development. For instance, the morpheme 'un-' means 'not', '-believe-' means 'accept as true or real' and '-able' denotes 'to be' so that 'unbelievable' means 'not to be believed'. Hence, morphological knowledge involves knowing how morphemes carry and alter meaning when used in different combinations. It has a powerful influence on oral language skills, spelling, word-level reading and reading comprehension development (Apel, 2014; Bowers et al., 2010; Goodwin & Ahn, 2013). Explicit teaching of morphemic and syntactic knowledge 'helps students order the words and phrases in their sentences to convey and to change meaning' (IOM & NRC, 2015, p. 110).

What does research say about effective teaching of vocabulary?

Describing specific vocabulary teaching strategies is difficult because studies of vocabulary rarely address specific instructional techniques in isolation (Cervetti et al., 2023; Marulis & Neuman, 2010). Nevertheless, there is sufficient evidence for successful strategies including the use of music, rhyme and prosodic texts (Davis, 2017; Engh, 2013). Further, pre-teaching vocabulary for new content and using predictive vocabulary strategies based on knowledge of semantic strategies have also been shown to help develop vocabulary for some students (Cervetti et al., 2023). Programs that use explicit instruction either through explanation of words or a key word have also been found to be more impactful than those that used implicit strategies (Marulis & Neuman, 2010).

Reading aloud to students

Numerous studies describe the impact on vocabulary development of reading aloud to students, particularly those with literacy learning difficulties (Buckingham et al., 2012; Denton et al., 2021; Duff et al., 2014; Gillon et al., 2020; Hempenstall, 2016; Munro, 2017; Ritter et al., 2013; Storkel et al., 2019). Incorporating targeted vocabulary instruction into shared book reading is effective and involves providing simple definitions of a group of target words while reading (Gillon et al., 2020).

Dialogic reading

Similarly, dialogic reading strategies improve vocabulary skills (Al Otaiba et al., 2018; Lonigan & Whitehurst, 1998; Shanahan et al., 2010; Whitehurst et al., 1994). These involve shared picture-book reading, using specific questioning and prompting strategies involving pre-teaching essential vocabulary to support early readers to recall information and draw inferences (Al Otaiba et al., 2018; Ramsey et al., 2021).

Pre and post activities

Other pedagogic strategies can build specific content area vocabulary using pre–post activities. These are activities teachers use to assess students' performance prior to a particular activity (pre) and after an activity (post). Pre-activities generate responses to new key content and reflective discussion of these responses leads students to further research into the new key content. Post-activities allow students to demonstrate knowledge of new curriculum content using expanded vocabulary and language structures to reflect on their learning (Cappello & Walker, 2020). Reflection leads students to develop awareness of new subject-specific language and expressions they have acquired and demonstrates their comprehension of new ideas in new content.

Structured literacy

Structured literacy can support the development of morphological skills. Four instructional approaches discussed in research include

- deepening students' awareness of the morphological structure of words

- teaching the meanings of affixes and base (or root) words

- strengthening morphological problem-solving or thinking about how a word's component morphemes contribute to its meaning or grammatical form, for example, by drawing analogies between base and derived pairs, detecting and correcting errors in spelling, creating new words with known/taught morphemes

- deriving the meanings of unfamiliar words as they are encountered in connected text) (Carlisle, 2010; Fallon & Katz, 2020).

Specific and explicit morphological instruction

There are reported benefits of specific and explicit instruction in morphological awareness based on an intervention that followed a decoding, vocabulary and fluency format (Denston et al., 2018; Marriott, 2013). This involved daily decoding practice incorporated into a classroom using unfamiliar words that were typically morphologically complex (Denston et al., 2018). Another study targeted specific affixes in words. This approach encouraged students to identify common orthographic patterns and meanings associated with the use of the target affixes (Good et al., 2015).

Phonemic awareness

Phonemic awareness is a subskill of phonological awareness and essential to reading development, as it has been found to be a strong predictor of later reading ability (Ehri et al., 2001; Hulme et al., 2012; Melby-Lervåg et al., 2012). Poor phonemic awareness contributes to reading delays, as well as dyslexia (Denton et al., 2021). Students who are phonemically aware possess the ability to hear, identify and manipulate the smallest units of 44 sounds in spoken English words (Gillon, 2005; Hempenstall, 2016; Moats & Tolman, 2019). Phonemic awareness is a crucial skill for learning to read, as it enables students to blend phonemes together to make words and segment words into their separate sounds (Foorman et al., 2015; Rohl, 2000). It is foundational to decoding and applying the alphabetic principle, where phonemes are mapped to graphemes. Research shows that the explicit teaching of phonemic awareness improves that awareness, as well as reading and spelling. Further, phonemic awareness interventions were found to be more effective at improving reading skills than phonics interventions, particularly in preschool and the early years of formal schooling (Suggate, 2016).

Figure 1 shows how phonemic awareness builds on a student's ability to identify individual words from a stream of speech, break words into syllables, and identify and produce rhyming words. Phonemic awareness can be thought of as a set of separate but related skills – phoneme isolation, phoneme segmentation, phoneme blending and phoneme manipulation. There are, however, differing views as to whether alliteration is a phonological awareness or phonemic awareness skill (Ehri & Nunes, 2002; Gillon, 2005; Moore et al., 2005). Phonemic awareness subskills develop in complexity from the lower order skill of identifying initial phonemes in a word, to the higher order skills of manipulating phonemes.

Figure 1 A continuum of complexity of phonological awareness (Adapted from Chard & Dickson, 1999, p. 262)
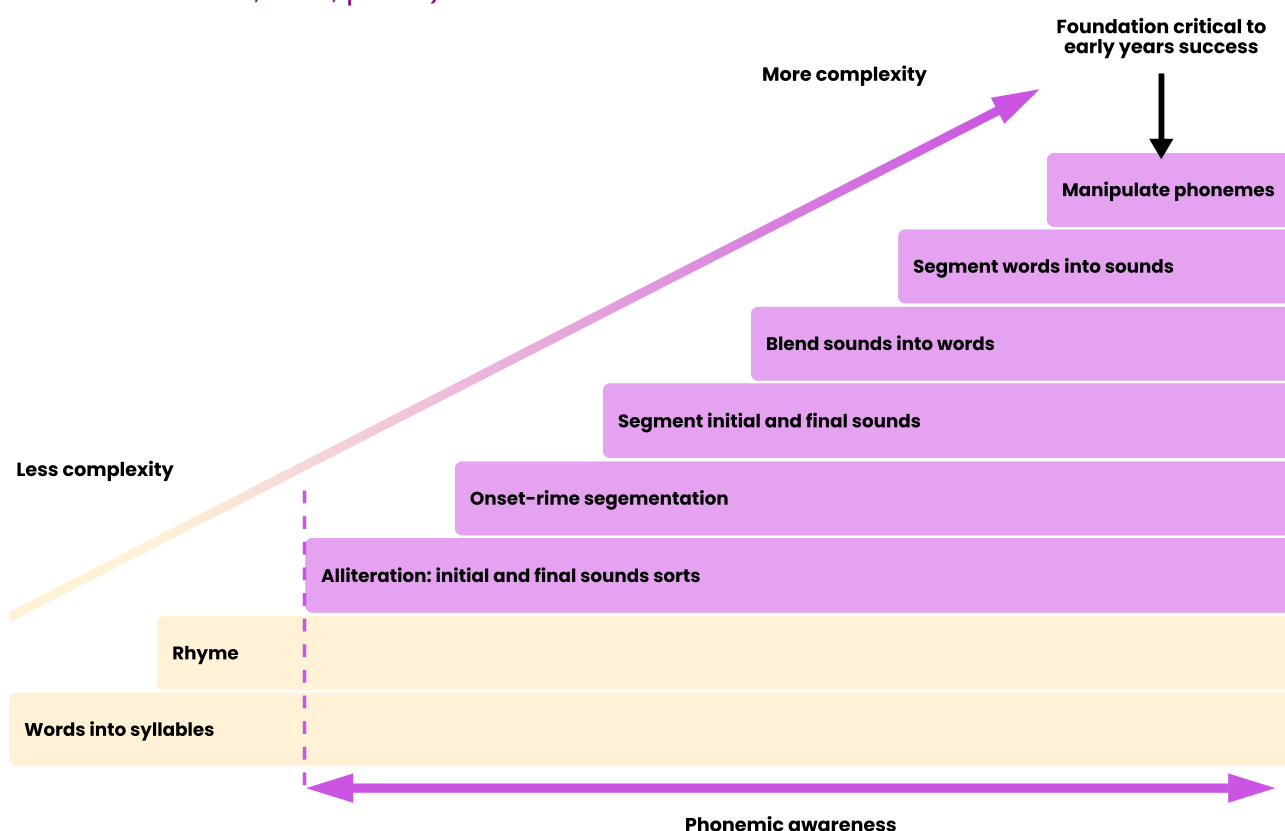
What does research say about effective teaching of phonemic awareness?

The teaching of phonemic awareness supports the reading development of students achieving at expected levels and for students with possible literacy learning difficulties. Researchers agree that phonemic awareness needs to be explicitly and systematically taught to develop students' reading skills, including decoding and encoding (Al Otaiba et al., 2018; Denton et al., 2021; Hempenstall, 2016). Instruction in phonemic awareness does not need to be lengthy to be effective and can be heightened when taught in conjunction with phonics, allowing learners to manipulate both graphemes and phonemes (Castles et al., 2009; Ehri & Nunes, 2002; Gillon, 2005).

Consolidate underlying subskills

When teaching phonemic awareness, it is important to confirm whether students have consolidated the underlying hierarchy of phonological awareness skills, as it is unlikely they will be able to break words into separate phonemes if they cannot break words into syllables. The skill of isolating phonemes in simple and short words (e.g. consonant-vowel-consonant words) generally begins with students identifying initial phonemes, followed by final phonemes and then medial phonemes. Words with an increasing number of phonemes are more difficult to blend and segment, as the task makes greater demands on working memory (Rohl & Pratt, 1995). Therefore, when teaching phonemic awareness the number of phonemes in words used for instruction should be considered (e.g. using 2- or 3-phoneme words for early instruction), as well as the graphemes represented, as it is more difficult to segment phonemes in words containing consonant blends (e.g. clap, bent) (Ehri & Nunes, 2002; Rohl & Pratt, 1995).

Phoneme manipulation, the most complex of the phonemic awareness skills, involves the manoeuvring of phonemes. Here phonemes can be added, deleted or substituted in any position of a word to make a new word. Table 2 provides examples of each phonemic awareness subskill. These skills are fundamental in their support of phonics.

Table 2 Phonemic awareness and example subskills

Phonemic awareness skill	Example
Phoneme isolation	What is the first/last phoneme in feet?
Phoneme blending	Put these phonemes together /b/-/a/-/ck/; what word do they make?
Phoneme segmentation	Stretch out the word kite; how many phonemes can you hear?
Phoneme manipulation	What word would you make if you replace the /d/ in card with /t/? What word would you make if you removed the /k/ from the word fork?

Phonics

Phonics involves combining knowledge of English phonemes (phonemic awareness) with knowledge of English letters (graphemes) to decode words (Rohl, 2000). Once students understand that writing conveys meaning and that the spoken words associated with print remain constant, they may be ready to learn to decode texts. Phonics skills are fundamental in supporting the interpretation of meaning.

Phonics develops through establishing the alphabetic principle, which is the understanding that letters represent sounds in given languages and, in this instance, English. English has 26 letters (graphemes) and 44 sounds (phonemes), and each phoneme can be mapped either to a single grapheme, or to a cluster of graphemes. For example, the initial phoneme /c/ in 'cat', 'kite' and 'Christmas' is represented with different graphemes. Conversely, some graphemes or grapheme combinations may map to multiple phonemes. For example, 'c' maps to /k/ in 'cat' and /s/ in 'city' just as 'qu' maps to /ck/ in 'cheque' and /kw/ in 'quick'.

The science of reading demonstrates that grapheme–phoneme correspondence (GPC) knowledge and orthographic mapping are critical to efficient word reading (e.g. Castles et al., 2018; Ehri, 2014; Graham et al., 2020; Levin & Ehri, 2009). Researchers have demonstrated that learning to read single words is likely to be most successful when students already understand basic GPCs.

Grapheme–phoneme correspondences support automatic orthographic mapping that 'occurs when, in the course of reading specific words, readers form connections between written units, either single graphemes or larger spelling patterns, and spoken units, either phonemes, syllables or morphemes' (Ehri, 2014, p. 5). To decode texts students must learn the range of GPCs where the same phoneme may have multiple grapheme correspondences (see Table 3). This process allows students to access a range of words including high frequency words or any words automatically, giving them immediate access to the meanings of a range of texts and building on their current understanding of whatever subject matter the texts address.

Table 3 Phonemes with multiple grapheme correspondences (adapted from Burkins & Yates, 2021, p. p. 96)

Word	Phonemic analysis	Orthographic analysis	Orthographic mapping
they	/th/ /ay/	t-h-e-y	th/ey
laugh	/l/ /a/ /ff/	l-a-u-g-h	l/au/gh
does	/d/ / ə / /z/	d-o-e-s	d/oe/s
knight	/n//igh//t/	k-n-i-g-h-t	kn/igh/t

What does research say about effective teaching of phonics?

While teaching the alphabetic principle can seem complex, the number of GPCs is finite. Coltheart et al. (2001) estimated that approximately 80 per cent of English single syllable words and non-words can be pronounced using a small set of letter–sound relationships. Therefore, instruction in phonics gives students access to a high proportion of the words they will encounter in early reading, which makes phonics an empowering skill set. Students need to apply the alphabetic principle using GPCs and blending the phonemes together. Reading phonetically regular words and non-words plays an important role in identifying whether students are using decoding skills (Castles et al., 2018).

Explicit and systematic phonics teaching

Phonics is best taught explicitly and systematically (National Reading Panel, 2000; Rose, 2006; Rowe, 2005). Explicit teaching involves the direct teaching and modelling of key concepts (Denton, 2012; Quick, 2020). Systematic teaching involves deliberately ordering and structuring what is taught (Al Otaiba et al., 2018). Explicit teaching and systematic teaching benefit all students, particularly those with low language and literacy skills on school entry (Snow & Juel, 2005) and therefore should be present in any classroom. These 2 teaching approaches are beneficial when intentionally applied to teaching phonics (Castles et al., 2018). Although there are several approaches to teaching phonics, since the Rose report (2006) attention has focused largely on synthetic phonics.

Synthetic phonics

Synthetic phonics is a widely used approach that involves synthesising or blending individual sounds together to convert graphemes into phonemes (e.g. to pronounce each letter in 'stop', /s/-/t/-/o/-/p/) and then blend the phonemes into a recognisable word (Rowe, 2005). This is an explicit approach. The teaching approach is also systematic in that the selected letter–sound patterns taught can be made into many different words. This allows students to start synthesising and applying their decoding skills to word reading as early as possible. Word reading can then be practised using decodable texts that support and consolidate students' phonics knowledge and skills (Castles et al., 2018).

Additional support

Generally, explicit, systematic instruction in synthetic phonics is an effective strategy, but some students require further support. Students with literacy learning difficulties and other at-risk students benefit most from explicit instruction for the learning of new processes, concepts, and content. Research emphasises whole class and small group instruction in phonics, particularly in isolating phonemes and linking them to graphemes (Hempenstall, 2016). Other findings support this. They include an emphasis on mastery learning, daily opportunities to learn and consolidate the content, and instructional practices that connect related content, for example connecting phonics and phonemic awareness to reading and writing (Al Otaiba et al., 2018). Further, a one size fits all approach may not be suitable for students with literacy learning difficulties, as their needs are wide-ranging (Denton et al., 2021).

Reading fluency

Reading fluency refers to accurate, expressive reading aloud with appropriate attention to phrasing and punctuation (Konza, 2011; Kuhn et al., 2010). While it includes reading subskills such as word-level reading of irregular, high frequency words (Graham et al., 2020) and saying letter–sounds and phonemes fluently (Alonzo & Tindal, 2007; Carson et al., 2019; Foorman et al., 2015), in this synthesis we refer to reading fluency in relation to the reading of connected text. As students develop reading fluency, they prioritise their cognitive resources to comprehension (Wolf & Katzir-Cohen, 2001), resulting in meaningful and enjoyable experiences of reading as they move from 'learning to read' to 'reading to learn'. Teaching and monitoring the development of fluency involves 3 key subskills: accuracy, speed, and prosody (Fuchs et al., 2004; Suggate, 2016; Valencia et al., 2010).

Accuracy means reading words correctly, which is necessary in achieving fluency. Speed refers to how quickly words are read. A student's reading accuracy and speed are measured together by recording the number of correct words read per minute, which is also described as Oral Reading Fluency Assessment (Alonzo & Tindal, 2007; Grima-Farrell, 2014). The more fluently that students read a particular text, the more likely they are to comprehend it, although there is some evidence that reading accuracy has a greater impact on reading comprehension than reading rate (Allington, 2011; Burns, 2024; Konza, 2011). While Abadzi (2016) identified 45–60 correct words per minute as a benchmark minimum level of fluency in almost all languages to support basic comprehension, deeper comprehension requires an accuracy ranging between 93 and 97 per cent of words read (Allington, 2011; Burns, 2024; Konza, 2011). However, it takes more than accuracy and speed to become a skilled reader; reading well requires prosody.

Prosody is the use of appropriate expression and intonation coupled with phrasing to enhance and maintain meaning when reading (Kuhn, et al., 2010, Miller & Schwanenflugel, 2006, 2008; Schwanenflugel et al., 2004). Two approaches have been used to describe and evaluate prosody: automated assessment and human judgement. Automated assessment involves using a spectrometer, a sonic measuring device, to observe the changes in intonation and are undertaken by specialists in such technologies. Human judgement usually requires rubrics, such as the National Assessment of Educational Progress Scale (NAEP, 2018) and the Multi-dimensional Fluency Scale (Zutell & Rasinski, 1991). The NAEP Scale uses a descriptive rubric to support teachers to rate the expression, intonation and response to punctuation and meaning as they read. The Multi-dimensional Fluency Scale requires teachers to consider multiple factors in rating students' oral reading including intonation, pausing, expression and volume, phrasing and smoothness. Teaching students to modulate their tone, volume, phrasing and expression to enhance the meaning of what they read is an important skill that both supports and demonstrates comprehension.

What does research say about effective teaching of fluency?

Students with reading comprehension difficulties may require interventions targeting reading fluency and oral language instruction (Spencer & Wagner, 2018). Narrative interventions for improving oral language comprehension and production have been shown to improve both oral narrative skills and language comprehension, as well as reading comprehension (Gillam et al., 2023). Dialogic approaches to reading comprehension have been found to link oral language development to reading comprehension and hence improve fluency (Al Otaiba et al., 2018).

Repeated reading

A synthesis of fluency intervention research from 2001 to 2014 examined reading fluency and comprehension outcomes of reading fluency interventions for students with language learning difficulties in kindergarten through to fifth grade. Results suggested that repeated reading, multicomponent intervention and assisted reading with audiobooks produced gains in reading fluency and comprehension.

> Providing a model of fluent reading and performance feedback, using texts that are well within students' independent reading level, setting a performance criterion, and practicing repeated reading with peers also contributed to improved outcomes (Stevens et al., 2017, p. 576).

Repeated reading of a passage at least 4 times increased reading fluency more than reading a passage 2–3 times (Suggate, 2016). Repetition is a critical variable, with automaticity being based on retrieval (memory) rather than adjustment of other reading skills.

Sustained practice reading aloud authentic texts

Achieving fluency requires sustained practice in reading aloud. Castles et al. (2018) identify the importance of decodable texts in the early stages of developing fluency; however, they note that 'once students move beyond the very early stages of reading, the benefits of decodable readers are likely to be outweighed by their limitations' (p. 16). Decodable texts tend to be low-quality literature with a restricted range of words. They may not engage the reader or help build students' vocabulary and knowledge through reading. As soon as decoding skills are mastered, readers should start reading authentic, good-quality texts intended for early readers that are engaging and have a range of vocabulary. The combined impact of applying knowledge of vocabulary to all the orthographic patterns results in the ultimate goal of reading – reading comprehension.

Reading comprehension

Reading comprehension is a complex and active process that is at the heart of reading. It requires the use of cognitive, linguistic and perceptual skills to make meaning from written symbols. Reading comprehension involves identifying individual words in texts (decoding) and constructing meaning from them using language comprehension skills (Nation, 2019). Rich mental models then form which build cumulatively as an individual reads (Castles et al., 2018). Along with being a key skill for content learning in school, reading comprehension is connected to academic achievement and life success (National Reading Panel, 2000; Snow, 2002). The process of achieving proficiency in reading and reading comprehension spans years, as it encompasses comprehension of language and mastery of its written representation. Most research in this area has focused on the comprehension practices of strong readers (Castles et al., 2018; Duke & Pearson, 2002).

The key constructs that support the development of reading and reading comprehension have been discussed in previous sections of this synthesis. Reading comprehension begins with the decoding and understanding of individual words, sentences and passages containing familiar vocabulary and ideas. It then moves to more complex texts containing subtle layers of meaning, more complex vocabulary and unfamiliar ideas. Therefore, oral language, vocabulary, phonemic awareness and phonics development all contribute to the development of reading comprehension. There is overlap in the acquisition of these essential constructs, with greater focus on certain constructs at specific stages of development.

The reader's background knowledge is also important in making meaning and interpreting texts. (McNamara & Magliano, 2009; National Reading Panel, 2000). An author assumes a level of general knowledge when they write a text; knowledge the reader may or may not hold. Thus, the experiences and understandings the reader brings to the text contribute to or inhibit comprehension, particularly if they are partially formed or absent, or are based on misconceptions. The effects of background knowledge can also impact comprehension despite the skill level of the reader (Smith et al., 2021). Skilled and low-skilled readers who have a depth and breadth of knowledge related to the text they are reading, 'are more able to comprehend what is being read, than when reading a text for which they lack background knowledge' (Smith et al., 2021, p. 226).

Specific language comprehension skills that contribute to the development of reading comprehension are also important. Ever-increasing knowledge of vocabulary and syntax is used to construct the literal meaning of a text, while knowledge of text structure, inferencing, and comprehension monitoring are used to build on current understanding (Hogan et al., 2014; National Reading Panel, 2000). Vocabulary, syntax, text structure, inference, comprehension monitoring, and background knowledge all support language comprehension through the development of a mental model (Kintsch & Kintsch, 2005).

What does research say about effective teaching of reading comprehension?

There is a plethora of research describing how to teach reading comprehension. The National Reading Panel report (2000) identified 8 instructional strategies that had a scientific base considered effective for teaching reading comprehension. These are: comprehension monitoring, cooperative learning, graphic organisers, question answering, question generation, story structure,

summarisation, and multiple strategy instruction. Strategy instruction involves teaching processes and techniques that help students construct meaning and remember what is read. Effective reading comprehension instruction was also found to include emphasis on both narrative texts (such as novels) and expository or explanatory texts (such as those common to the humanities, mathematics or science classrooms). Here, the National Reading Panel (2000) stresses that teachers need a depth of knowledge and an understanding of the kinds of instruction that can be used to teach the comprehension strategies successfully. These strategies are summarised in Table 4; however, it is important to note that for reading comprehension 'teaching students multiple strategies is more effective than teaching single strategies' (National Reading Panel, 2000, p. 32).

Table 4 Reading comprehension strategies identified by the National Reading Panel (2000)

Reading comprehension strategy	How it is taught
Comprehension monitoring	Teach students to attend to and monitor their own understanding of a text (metacognitive awareness). Teach them clarifying as a skill e.g. through rereading, applying background knowledge, inspecting illustrations or seeking help.
Cooperative learning	Involve students in learning reading strategies together in groups to come to shared meanings.
Graphic organisers	Teach students to use graphic organisers as visual summaries. Involve them in translating text into charts or graphics that show the important ideas and their interrelationships e.g. hierarchical trees (general information at the top, more specific ideas linked below), Venn diagrams (illustrating similarities and differences), etc.
Question answering	Ask students to answer questions consolidating what is learnt from the text and what to do if the question cannot be answered.
Question generation	Teach students to guide their recall of a text by having them ask questions and then remember or figure out the answers e.g. who, what, when, where, why, how questions; or questions that focus on certain information such as main ideas (literal comprehension) and implied ideas (inferential comprehension).
Story structure	Teach students to use the structure of the story to recall story content so they can answer questions about what they have read. This strategy is useful for less skilled readers.
Summarisation	Teach students to reduce text to the most important information by showing them how to select key information, to delete what is not important, and to paraphrase. This might include instruction in main ideas, selection, or invention of topic sentences. Summaries can be developed at the end of a text or several times along the way.
Multiple strategy instruction	Model the use of 2 or more of the strategies in this table to show how to maintain meaning.

Unsurprisingly, explicit teaching is a strategy found to increase reading comprehension. Teaching reading comprehension involves explicitly teaching the underpinning skills, such as word reading and language comprehension (Catts, 2018; National Reading Panel, 2000). Explicit teaching of background knowledge also enhances reading comprehension by fostering engagement and improving motivation (Duke & Cartwright, 2021). Further, the explicit teaching of text structures increases reading comprehension, as familiarity with text structures allows the reader to focus on the most significant details within a text (Gersten et al., 2001; Hogan et al., 2011).

Overall, the evidence indicates that the most effective interventions for teaching reading comprehension target background knowledge and the constructs of the science of reading discussed in this literature review (Apel et al., 2012; Duke & Cartwright, 2021; Foorman et al., 2018; Smith et al., 2021).

Conclusion

This synthesis presents the science of reading as a body of empirical evidence consisting of 6 constructs. This evidence continues to grow as the research expands. It is not static – it evolves; and our understanding of the applications of neuroscience, cognition and pedagogical practices evolve with it. The research evidence clearly shows that many of the constructs that make up the science of reading should be taught early and explicitly to support students' reading development. Finally, it is evident in the research that the science of reading is neither a program, a strategy nor a suite of materials. Rather it represents the knowledge, skills and strategies that need to be taught if all students are to become proficient readers.

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