

PRE-SERVICE TEACHERS ARE COMPETENT IN PHONOLOGICAL PROCESSING SKILLS: HOW TO TEACH THE SCIENCE OF READING

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Approximately 20% of students experience reading failure each year. One of the difficulties associated with this large percentage is that it has been documented that pre-service teachers may not be receiving the most appropriate training regarding reading acquisition. The present study sought to determine if pre-service teachers were proficient in phonological processing skills and thus capable of learning concepts for which these skills are prerequisite. One-hundred sixty-four participants (85 pre-service teachers and 79 non-education majors) were administered the Comprehensive Test of Phonological Processing (CTOPP). The results indicated that pre-service teachers' phonological processing skills were sufficiently developed and not significantly different from non-education majors or from the CTOPP's normative sample. These students have the ability to learn the concepts related to the science of reading. Components of an appropriate curriculum for pre-service teachers such that they can acquire this knowledge are discussed.

Learning to read is arguably one of the most complicated and important skills in which humans engage. Academic and career success are dependent on proficient reading skills. Unfortunately, 15% to 20% of students in the United States have serious difficulties learning to read (Shaywitz, 2004; Tallal et al., 1996). In 2013, 32% of fourth graders were reading at a level below basic and 65% were reading at a level below proficient. Reading at the basic level indicates partial mastery of the skills necessary for proficient work at a particular grade level. Reading at the proficient level indicates students have demonstrated their competency to read challenging material (National Center for Educational Statistics

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[NCES], 2013). These percentages have not changed substantially since 1992, when the percentage of students reading below basic and proficient was 38% and 71%, respectively (NCES, 2013). Although considerable concern and effort have been directed at the issues related to students who are performing poorly in reading, the data suggest that little progress has occurred.

These concerns regarding reading are certainly not new. Three decades ago, the National Commission on Excellence in Education provided ample evidence that many of our nation's children experienced academic difficulties that resulted in poor reading and mathematics proficiency, which persisted into adulthood (National Commission on Excellence in Education, 1983). Since that time, several key pieces of legislation were enacted that attempted to rectify these issues (Improving America's Schools Act, 1994; Goals, 2000: Educate America Act, 1994; No Child Left Behind Act, 2002). Although these efforts highlighted the difficulty and, in the case of the No Child Left Behind Act, created enormous accountability requirements for teachers and school systems, academic performance has not changed, and a nearly equal percentage of students are continuing to experience reading failure. Educational critics have argued that poor classroom instruction, particularly for very low-performing students, has been partially responsible (Reutzel & Smith, 2004).

Although the Common Core State Standards (CCSS, 2010) is a set of standards that guides student knowledge and is not a curriculum, it sets expectations for what students should acquire in their learning and thereby informs curriculum development. The CCSS are considerably different from previous individual state standards and have higher expectations (Porter, McMaken, Hwang, & Yang, 2011). Even when the intention is to provide standards on which curricula could be developed to reach high expectations with regard to reading, the result are often less than satisfactory. The CCSS was developed to provide a consistent framework of standards, to better track and assess transient students, and to increase educational expectations so that when students graduate, they would be competent to compete in society including the global economy. Although the CCSS were developed based on research and evidence-based practices, due to public input from university professors, advocacy groups, state departments of education, and publishers, the standards fell short

for reading, particularly for struggling readers (Moats, 2012). The major difficulty was that CCSS did not include research-based standards and, therefore, will not help inform educators of the best practices available to assist struggling readers (Moats, 2012). Even when enormous efforts have been placed in developing standards, as was the case for CCSS, political and philosophical compromises abound, the tenets of the science of reading¹ are ignored and the likelihood of instructional strategies that are appropriate for struggling readers are not widely dispersed or known. As an example, teacher knowledge regarding reading acquisition and reading difficulties has been assessed by several researchers. Many teachers lack the basic knowledge that is required to teach reading acquisition (e.g., Bos, Mather, Dickson, Podhajski, & Chard, 2001; Cunningham, Perry, Stanovich, & Stanovich, 2004).

Early identification and subsequent intervention are key aspects in the prevention of reading disabilities (Bos, Mather, Narr, & Babur, 1999; Coyne, Kame'enui, & Simmons, 2004; Partanen & Siegel, 2014; Weiser & Mathes, 2011). It is imperative that instructional strategies that can prevent early school failure be developed (Ziolkowska, 2007) and that these strategies be taught to pre-service teachers so that they can be implemented in elementary classrooms. Theoretically, classroom instruction that provides appropriate skill development in the science of reading should reduce the prevalence of reading failure. There is considerable scientific knowledge concerning reading acquisition and the strategies that are the most effective in teaching children to read (Fletcher, Lyon, Fuchs, & Barnes, 2007; National Reading Panel, 2000). Even with this knowledge, as noted above, a large percentage of students experience reading difficulties. Lonigan and Phillips (2015), for example, reported that even after receiving three to four months of evidence-based general classroom instruction, larger than expected percentages of preschoolers (i.e. 58% and 72%, respectively, in their two samples) were scoring in the 25th percentile or lower on standardized measures of phonological awareness, print knowledge, and oral language, thus meeting criteria to participate in the more intensive, small-group instruction that was the focus of their study. Helping beginning readers understand the nature of the code-based alphabetic writing system and providing them with direct instruction

regarding phonemic awareness, decoding skills, and related tasks is paramount when teaching reading acquisition, results in a significant decrease in reading failure, and should reduce the dependence on remedial intervention programs (Foorman, Francis, Fletcher, Schatschneider, & Mehta, 1998; Foorman & Torgesen, 2001).

Mastery of the alphabetic principle and phonological awareness are critical to reading acquisition and development; students rely on this knowledge to recognize letter and sound patterns which aid in accurate word identification (Ehri, 2005; Preßler, Konen, Hasselhorn, & Krajewski, 2014). Unfortunately, many students with reading difficulties lack knowledge of the alphabetic principle and an understanding of phonemic awareness, along with other potential deficiencies. Measures of word identification, alphabetic principle, fluency, and phonemic awareness have all been found to be consistent predictors of a child's responsiveness to intervention (Lam & McMaster, 2014). Students who are at risk for reading failure struggle to use these abilities, which leads to poor decoding skills and difficulty learning new words (Ehri & Saltmarsh, 1995; Reitsma, 1983), which can persist for years (Eklund, Torppa, Aro, Leppanen, & Lyytinen, 2015). For these students, acquisition of these skills is prerequisite to becoming successful readers.

As both phonological processing and alphabetic awareness are critical components of reading acquisition, it is imperative that pre-service teachers not only possess these skills and knowledge themselves but are capable of teaching these constructs to young students. These issues were reflected in a best-evidence synthesis of studies examining initial (i.e. non-remedial) reading instruction of Kindergarten to 5th-grade students (Slavin, Lake, Chambers, Cheung, & Davis, 2009). The synthesis identified children as "beginning reading" (Kindergarten to 1st grade; 63 studies) or "upper elementary" (2nd to 5th grades; 79 studies) students, as well as defined and compared four categories of reading instruction: (a) reading curricula and core reading textbooks, (b) instructional technology, such as computer-enhanced lessons, (c) instructional process programs, which provide teachers with additional training regarding reading instruction, and (d) a combination of curricula and instructional process programs. Findings pointed to instructional process programs—those that provide

professional development for teachers, transform their day-to-day instructional practices, emphasize cooperative learning, and/or include instruction on phonics and phonological awareness—as being more successful than curricula or instructional technology practices alone. Slavin and colleagues discovered that the most successful programs for both beginning readers and upper elementary students included extensive professional development for teachers that provided them with explicit instructional strategies in the science of reading. These outcomes were echoed for schools with high poverty rates (Slavin et al., 2009).

Washburn, Joshi, and Binks-Cantrell (2011) examined pre-service teachers' knowledge of phonological awareness, phonemic awareness, phonics/alphabetic principle, morphology, dyslexia, and comprehension and not only found that pre-service teachers lack the knowledge necessary to teach struggling readers but believed that letter and word reversal was a characteristic of dyslexia. These authors reported in a later study that pre-service teachers in both the United States and the United Kingdom hold similar misconceptions about dyslexia, including that it is a “deficit in visual perception” (p. 13) and, again, that they believe it is characterized by the reversals of letters and words (Washburn, Binks-Cantrell, & Joshi, 2014). Studies examining the effectiveness of professional development opportunities designed to help in-service teachers gain explicit instruction language concepts found that these deficiencies in knowledge can be corrected. Washburn and colleagues found that pre-service teachers' lack of knowledge was related to their lack of training. Pre-service teachers who have even one additional course and practicum in reading instruction for children with reading difficulties can demonstrate significantly more content knowledge and self-efficacy than those who do not receive additional training, even when both groups have prior coursework and practice in reading and language arts instructional methods (Leader-Janssen & Rankin-Erickson, 2013).

In-service teachers' knowledge has also been examined and, despite all that is known regarding the elements of effective reading instruction gained from the science of reading, teachers are continuing to enter their field unprepared to teach phonological awareness (Lieberman, Shankweiler & Lieberman, 1989; Moats, 2009). In-service teachers have acknowledged a need for

additional training regarding instruction (Clark, Jones, Reutzel, & Andreasen, 2013). Research supports their acknowledgement: In Cunningham and colleagues' (2004) phonological awareness task, 722 in-service teachers were presented with 11 words and asked to identify the number of phonemes in each word. Twenty percent were incorrect on all 11 items, 30% were incorrect on half the items, and less than 1% answered all 11 items correctly. Teachers demonstrated similar results regarding their explicit knowledge of phonics. During debriefing, teachers reported that they had not received explicit instruction regarding phonological processing during their academic training (Cunningham et al., 2004).

Cheesman, McGuire, Shankweiler, and Coyne (2009) mailed the Survey of Teacher Phonemic Awareness, Knowledge, and Skills (PhAKS) to 475 first-year teachers examining their knowledge of phonological awareness instruction and phonological awareness skills. The 15-item PhAKS included nine multiple-choice items regarding phonemic processing instruction definitional terms such as phoneme and phoneme awareness, and asking questions regarding phoneme awareness (e.g., "Effective phonemic awareness instruction teaches children to? Which task requires more refined phonemic awareness?") and six items examining their phonological processing skills (e.g., "Can the words, shoe, do, flew, and you be used to illustrate oral rhyming? Which list shows a systematic sequence in counting sounds in words, from easy to complex?"). Of the 475 surveys distributed, 223 were returned. Of those who returned their surveys, only three participants (1.3%) correctly answered all of the items. Only 18% correctly answered 12 of the 15 items (80%), the criterion used in the study suggesting these teachers had adequate knowledge of phonological awareness. Nearly one third of the teachers admitted they have a limited knowledge of phonological awareness instruction (i.e. "I'm not sure"). Although 56% understood the importance of phonological awareness, only 41% could correctly identify its definition (Cheesman et al., 2009).

Further, a teacher's general education, experience, and perception of knowledge do not necessarily translate to actual knowledge regarding students' reading acquisition and the skills involved in teaching them. Despite being experienced and well-educated, teachers in Piasta, Connor, Fishman, & Morrison's

(2009) study generally demonstrated low levels of the explicit, specialized knowledge necessary to effectively provide reading instruction to students. While pre-service teachers perceive that their ability to teach reading increases as they progress through their training (Clark et al., 2013; Leader-Janssen & Rankin-Erickson, 2013), they have also been found to overestimate their knowledge of phonological awareness (Cunningham et al., 2004). Clark and colleagues' (2013) qualitative results suggested that a large percentage of self-rated "average" teachers may be using strategies in the classroom that have been found empirically ineffective and were discouraged in their training programs.

Teacher training programs generally fail to provide adequate instruction and acceptable resources (e.g., textbooks) for teaching students reading acquisition. Instead, teachers must rely on their own skills, other resources, and future professional development opportunities. Greenberg, McKee, and Walsh (2013) discovered that most colleges of education encourage pre-service teachers to "develop their own personal philosophy of reading" (p. 40) rather than teach pre-service teachers the mechanics of the science of reading. As many as 866 different textbooks were being used in courses designed to teach reading acquisition strategies to pre-service teachers, while only 17 different texts were used in teaching pre-service teachers in mathematics courses (Greenberg et al., 2013). In a 2006 examination by the National Council on Teacher Quality (NCTQ) of college-level reading courses, authors counted a textbook as an acceptable example of a core resource for the course if it "accurately and thoroughly covers all five components of good reading instruction" (Walsh, Glaser & Wilcox, 2006, p. 19), which they identified as phonemic awareness, phonics, fluency, vocabulary, and comprehension. The four textbooks found to be acceptable in a survey of 227 were used in fewer than 5% of the courses examined (Walsh et. al, 2006). Joshi, Binks, Graham, and colleagues (2009) also examined the use of textbooks containing the five components recommended by the NCTQ and reported similar findings. Additionally, the researchers found that comprehension (1% to 20%) was generally covered to a greater extent than phonemic awareness (1% to 5%), although phonemic awareness is considered necessary for reading acquisition and, by extension, reading comprehension. It was also found that inaccurate information was frequently presented

in widely-used textbooks (Walsh et al., 2006; Joshi, Binks, Graham, et al., 2009). Hayward, Phillips, and Sych (2014) more closely examined the type and breadth of errors present in pre-service textbooks. Twenty-eight chapters published between 2001 and 2011 that were specifically directed toward the teaching of phonological awareness were included in the study. None were error free. Many omitted definitions of key terms, provided misinformation regarding the nature of phonological awareness and relied too heavily on orthography (Hayward et al., 2014). This depiction suggests that colleges of education are providing content regarding reading acquisition that is far from the consensus that emerged from the National Reading Panel and encouraging a considerable variety of positions regarding teaching reading, all of which bears little resemblance to what is known about the science of reading.

Joshi, Binks, Hougén, and colleagues (2009) administered the Survey of Language Constructs Related to Literacy Acquisition to college and university instructors who taught courses related to reading acquisition. Only 54% of the participants could correctly define phonemic awareness. The inability to define such an important concept for reading clearly indicates that pre-service teachers are not receiving appropriate instruction to prepare them to teach students to read, particularly students who are at risk for reading failure, for instructors cannot teach what they do not know themselves (Binks-Cantrell, Washburn, Joshi, & Hougén, 2012).

It has been documented that teachers are not providing beginning readers with consistent and adequate reading instruction. Reading failure rates have not changed appreciably in several decades even though the scientific literature regarding reading, its subskills, and proper teaching techniques have been repeatedly substantiated. It is clear that pre-service teachers are not receiving proper instruction regarding the science of reading. Pre-service teachers, experienced teachers, and university instructors all perform poorly on measures of constructs relating to their knowledge of reading acquisition and literacy. These professional educators are also not familiar with or knowledgeable of phonological awareness in general. It is possible—though, we believe, unlikely—that pre-service teachers, who later become experienced teachers and then potentially university instructors, are deficient in phonological processing skills such that they are less

capable of engaging in tasks that require phonological processing. Thus, the lack of the ability to engage in phonological processing skills could be the reason for the resistance in teaching these concepts to future generations of teachers. Without the requisite skills in phonological processing, pre-service teachers would lack the foundational skills to comprehend concepts related to phonological processing. Additionally, these individuals would need to experience remedial intervention to improve their phonological processing skills prior to learning strategies to teach phonological processing skills to young students, if in fact they have deficient skill development in phonological processing.

However, while educators' knowledge has been widely examined, no studies to date have gone beyond survey research to directly assess the ability of pre-service teachers to perform tasks that demonstrate their development of phonological processing skills (such as deleting words from compound words; deleting syllables and phonemes from words; blending words to create compound words, syllables and phonemes to create words; repeating nonwords; rapidly naming letters; reversing phonemes; blending nonwords; and segmenting words and nonwords into their constituent phonemes). Previous research has only examined pre-service and teachers' abilities to demonstrate their conceptual knowledge of phonological processing, not directly assessing their actual phonological processing skills. Although one might hypothesize that any undergraduate student who was accepted into a teacher preparation program would be well equipped to engage in phonological processing, this is an empirical question that has not been sufficiently evaluated much less confirmed.

The present study was designed to examine the phonological processing skills of pre-service teachers. This should be differentiated from the well-documented deficiency of pre-service teachers' knowledge of phonological processing concepts witnessed in many studies. The concern of the present study was to determine if pre-service teachers actually lack the *ability* to recognize, manipulate and process phonological information, not whether they possess the *knowledge* of how to articulate the meanings of the concepts related to phonological processing. As such, the present study addressed the question of whether pre-service teachers possess a performance deficiency as well as a knowledge deficiency with regard to phonological processing.

Method

Participants

One hundred and sixty-four university students from a public, midwestern university that has a large college of education and whose history was heavily based in teacher preparation participated in the present study. Students were recruited into the study based on whether they were pre-service teachers (education majors) or non-education majors. Eighty five (85) students were pre-service teachers (64 women and 21 men), while 79 students were non-education majors and acted as the comparison group (39 women and 40 men). Thirty-seven different majors were represented in the non-education group. There were no significant main effects or interactions involving age between the pre-service and non-education majors groups, (all $ps > 0.32$; mean ages were 21.9, 21.7, 23.1, and 22.7 years, respectively for women pre-service teachers and non-education majors and men pre-service teachers and non-education majors), although all of the phonological processing scores examined in later analyses were age referenced in terms of standard and composite scores so that age effects would have been mitigated had there been a significant main effect or interaction involving age. The study was approved by the university's Institutional Review Board.

Materials

To assess phonological processing, the Comprehensive Test of Phonological Processing (CTOPP; Wagner, Torgesen, & Rashotte, 1999) was used. The CTOPP has adequate reliability and validity (Hurford, 2003). Reliability estimates averaged 0.88 for internal consistency and 0.81 for test-retest. Validity was well established which included content validity (item rationale, item response theory and differential item functioning analysis), criterion-related validity (several studies examining the CTOPP with the Woodcock Reading Mastery Test-Revised, Test of Word Reading Efficiency and Lindamood Auditory Conceptualization Test) and construct validity (confirmatory factor analysis, age differentiation, and group differentiation).

The following CTOPP subtests were administered: Elision, Blending Words, Memory for Digits, Nonword Repetition, Rapid Letter Naming, Phoneme Reversal, Blending Nonwords, Segmenting Words and Segmenting Nonwords. These subtests are combined to form the following composite scores: Phonological Awareness Composite Score (PACS; Elision and Blending Words), Phonological Memory Composite Score (PMCS; Memory for Digits and Nonword Repetition), Rapid Naming Composite Score (RNCS; Rapid Digit Naming and Rapid Letter Naming) and Alternate Phonological Awareness Composite score (APACS; Blending Nonwords and Segmenting Nonwords). The APACS was included along with the three other composite scores since it addresses phonological awareness with nonword stimuli. As a result, the APACS provides more depth and further compliments the other component scores.

Procedure

The CTOPP was administered individually to each participant in a quiet well-lit room free of distractions. The CTOPP was completed in one administration which lasted approximately 30 to 40 minutes per participant. Graduate research assistants who had training in intellectual assessment, advanced tests and measures, and specific training in the CTOPP administered the tests.

Results

The raw scores were converted to standard scores and composite scores before they were subjected to $2(\text{Major}) \times 2(\text{Gender}) \times 10(\text{Subtest})$ and $2(\text{Major}) \times 2(\text{Gender}) \times 3(\text{Composites})$ repeated measures analyses of variance, respectively.² The repeated measures occurred for subtest and composite score. As can be seen in Table 1, the results indicated that there were no significant main effects or interactions involving subtest standard scores; $F(1, 159) = 0.98, p > 0.32$, $F(1, 159) = 0.41, p > 0.52$ and $F(1, 159) = 1.58, p > 0.21$ for major, gender and Major \times Gender, respectively. Although there was a significant main effect of subtest, $F(9, 1431) = 30.64, p < 0.0001$, and an interaction of subtest and gender, $F(9, 1431) = 4.30, p < 0.0001$, there were no significant interactions involving subtest and major (all $ps > 0.09$). The

TABLE 1 Mean Standard Scores on the Subtests of the CTOPP by Group

Subtest	Group	
	Pre-Service Teacher	Non-Education Major
Elision	9.21 (2.52)	8.65 (2.64)
Blending Words	11.14 (2.64)	10.05 (3.00)
Memory for Digits	10.96 (3.3)	10.67 (2.57)
Rapid Digit Naming	10.44 (2.57)	10.52 (2.12)
Nonword Repetition	8.76 (2.11)	8.57 (2.32)
Rapid Letter Naming	9.61 (2.82)	10.19 (2.58)
Phoneme Reversal	10.07 (2.76)	9.82 (2.64)
Blending Nonwords	11.05 (2.60)	10.33 (3.03)
Segmenting Words	9.18 (2.44)	9.03 (2.68)
Segmenting Nonwords	8.47 (2.42)	8.35 (2.65)

Note: Standard deviations are contained within parentheses.

interaction of subtest and gender was due to women outperforming men on Elision and Blending Words while men outperformed women on Rapid Letter Naming (see Table 1). The standard scores for both groups were consistent with the average performance of the norm-referenced group.

When examining the composite scores, no main effects or interactions approached significance (all $ps > 0.47$). In addition, the mean composite scores were all within the average range (90 to 110, see Table 2). The composite scores for both groups were also consistent with the average performance of the norm-referenced group.

TABLE 2 Mean Composite Scores on the CTOPP by Group

Subtest	Group	
	Pre-Service Teacher	Non-Education Major
Phonological Awareness	100.95 (13.28)	95.90 (15.20)
Phonological Memory	98.73 (14.01)	97.99 (12.60)
Rapid Naming	98.62 (18.35)	101.52 (13.85)
Alternate Pho Awareness	98.55 (13.4)	96.23 (16.05)

Note: Standard deviations are contained within parentheses.

Discussion

The results of the present study indicated that there were no significant differences between the phonological processing abilities of pre-service teachers and university students who were not following a teacher certification program. Neither group demonstrated significant differences in skills from those of the standardization group used to create the norms for the CTOPP. The phonological processing skills of both groups were well within the average range of the CTOPP norming group. As a result, any differences in knowledge or competence regarding phonological processing in pre-service teachers cannot be attributed to deficiencies in their skills or abilities to perform phonological processing tasks. Pre-service teachers do not possess a performance deficiency with regard to phonological processing skills. When previous literature is also taken into consideration, these findings suggest that the lack of competence regarding pre-service teachers and later experienced teachers to perform on surveys and quizzes concerning their knowledge of the concepts of phonological processing can be attributed to a lack of formal education regarding the mechanics of phonological processing. Pre-service teachers' poor performance on tasks that require a knowledge base to answer questions about the nature of phonemes, phonological processing, and other areas necessary to provide their students with appropriate reading acquisition instruction is due to a lack of exposure to these principles. Pre-service teachers are competent in phonological processing skills, they simply lack the prerequisite knowledge necessary for them to impart phonological processing concepts to their students as they relate to reading acquisition.

Previous research has demonstrated that many teacher education programs are not providing adequate experiences for pre-service teachers so that they can give effective reading instruction to beginning readers (American Council on Education, 1999; Hill, 2000; International Dyslexia Association, 1997; Liberman, 1987; Moats, 1999; Walsh et al, 2006; Washburn & Mulcahy, 2014). Early detection of phonological awareness problems may prevent reading difficulties (Alghazo & Hilawani, 2010; National Reading Panel, 2000). Pre-service teachers who do not fully understand the concept of phonological awareness cannot accurately teach

phonological awareness skills to young readers or develop appropriate interventions for struggling readers.

Reorganizing and restructuring teacher-preparation courses to include more instruction concerning phonological awareness is imperative, particularly given that pre-service teachers possess and are proficient in phonological processing skills. Moats (1999) suggested a core curriculum for pre-service teachers should include reading psychology and development, the structure of language, applying best practices in reading instruction and using validated, reliable and efficient assessments to inform classroom instruction. Even before the enactment of the No Child Left Behind legislation, there was enthusiasm regarding bridging the knowledge gained from the science of reading with curricula designed for pre-service teachers. Unfortunately, this enthusiasm has not resulted in wide-spread modifications to most colleges' of education reading curriculum for pre-service teachers, hence the impetus of Greenberg and colleagues' (2013) work to link evaluative scores to colleges of education so that individuals who have a desire to become competent teachers can make informed decisions regarding matriculation. Unfortunately, an alarmingly small number of teacher education programs provide coursework that presents the appropriate knowledge base of the science of reading to its students.

The present study indicated that pre-service teachers have appropriate and well-developed phonological processing skills which would allow them to benefit from proper instruction in the skills prerequisite for teaching reading acquisition if they would only be exposed to them. The root of the problem lies in colleges of education where the components of the science of reading are not taught. This complaint is certainly not a new one but is one that has caused a considerable amount of consternation within educational researchers, particularly researchers who have witnessed improvement in the reading skills of students who were previously experiencing reading failure until appropriate interventions were deployed (e.g., Blaunstein, Lyon, & Riccards, 2014).

Greenberg and colleagues (2013) found that only 22% of the 594 teacher certification programs received scores of three or higher on a four-point rating scale. Additionally, 78% of the elementary education programs received scores of 0 ("program coursework does not adequately address strategies for struggling

readers,” p. 41) for Standard 4: Struggling Readers, which is the standard most germane to the present study (Greenberg et al., 2013). This particular standard examined whether an elementary education program provided pre-service teachers with strategies to assist struggling readers. The only indicator for this standard assesses whether coursework provided pre-service teachers instructional strategies to assist struggling readers and to practice these strategies in the course. To determine if the course provided these strategies, textbooks and syllabi were examined. If the material from a textbook was assigned for students to read that covered strategies to assist struggling readers or the syllabus indicated documentation that this material would be presented in class, the standard was met. As the authors admitted, the requirement for a passing score on this standard was quite low. There was no assessment of quality using this method, simply if the material was indicated on a syllabus or known to exist in the textbook assigned for the course. One could argue that material is presented in class lecture and presentations that are not indicated in syllabi; however, given the considerable evidence that pre-service and experienced teachers lack this knowledge, it seems quite unlikely that the explanation for not passing this standard was due to content actually being covered in courses but missing from syllabi.

Many syllabi can be examined via their posting on college or university’s web pages, which can be very helpful in determining if a course reflects the science of reading. The phrase “develop your own personal theory of reading” is a red flag for a program that not only does not embrace what science has discovered regarding reading; it indicates that the instructor and potentially the entire department has no conception of the science of reading. Science education majors are not told that they will be required to develop their own personal theory of gravity. Science has determined the nature and properties of gravity in the same way that cognitive science has determined the nature and development of the neurological, cognitive, learning, and behavioral processes involved in reading. Although there is much to be learned regarding the development of the processes involved in reading, there is much to be learned with regard to the complete mechanics of the subparticles involved in gravity. Requiring students to “develop their own personal theory of reading” implies to students that there is no scientific understanding of the processes involved in reading and

that anyone's opinion, no matter how farfetched or how little it is based in science or reality, is as valid an approach to the nature of reading as any other. The underlying prerequisite skills and abilities for successful reading acquisition and development have been known and discussed in science for some time. Those who teach reading courses must be knowledgeable of the science of reading and must be held responsible for presenting that information to pre-service teachers. It is the most efficient and effective way to insure that our nation's students, particularly students at risk for reading failure, learn to read.

The difficulty appears to be that many colleges of education fail to provide the necessary coursework and content that is required for pre-service teachers to teach reading acquisition. More importantly, this lack of information and knowledge is detrimental to students who are experiencing reading failure. Approximately 20% of our nation's students are experiencing reading difficulties, and the percentage of fourth-grade students who are reading below basic and proficient (33% and 58%, respectively) has not appreciably changed since 1992. Fortunately, there is a solution. There is a scientific literature that prescribes how to improve reading abilities in young students. The solution involves providing pre-service teachers with the knowledge that will assist them to provide their students, particularly struggling readers, the types of assessment and interventions that will lead to improved reading skills. Reading courses must be developed or revamped to include the science of reading. In addition, pre-service teachers must be provided with the appropriate coursework such that they will be able to understand the mechanics of the science of reading prior to their exposure to that information.

Moats et al. (2010) developed the *Knowledge and Practice Standards for Teachers of Reading* for the International Dyslexia Association to act as a guide for the preparation and certification for individuals who will become teachers of reading and also as a guide for professional development for those who are current teachers of reading. As can be seen in Tables 3 and 4, the standards provide specific requirements regarding the essential knowledge (Section I) that a teacher of reading must have, as well as standards related to the demonstration of knowledge and skills that individuals who intend to provide services to individuals with dyslexia or other learning disorders should possess (Section II).

TABLE 3 Section 1 of the Knowledge and Practice Standards for Teachers of Reading

Section 1 Knowledge and Practice Standards	
Areas	Examples
Foundation Concepts about Oral and Written Learning	This section outlines the standards regarding the knowledge and application related to the influence that oral and written language contributes to reading and writing, cognition and behavior that affect reading and writing, environmental, cultural and social factors, typical development, causal relationships of the above, and reasonable goals and expectations for learning. Phonological, orthographic, semantic syntactic and discourse processing; attention, executive function, memory, processing speed, graphomotor control; development of oral language, phonological skill, printed word recognition, spelling, reading fluency, reading comprehension, written expression.
Knowledge of the Structure of Language	This section outlines the standards that refer to the individuals teaching reading should have regarding the structure of language with regard to phonetically regular and irregular words, common morphemes, and sentence structure. Phonology (concepts regarding vowels and consonants), orthography (graphemes, high frequency and irregular words, orthographic rules, syllable types), morphology (common morphemes in the English writing system), semantics (semantic organization), syntax (distinguish phrases, dependent and independent clauses in sentences, parts of speech) and discourse organization (narrative and expository discourse, construct expository paragraphs, identify cohesive devices in text).

(Continued on next page)

TABLE 3 Section 1 of the Knowledge and Practice Standards for Teachers of Reading (*Continued*)

Areas	Section 1 Knowledge and Practice Standards	Examples
Structured Language Teaching: Phonology	<p>This section outlines the standards that refer to teaching phonology. Underdeveloped phonological processing has been identified as a core weakness in individuals who have dyslexia. Teaching phonological processing skills is a very important component in remediating poor reading skills.</p> <p>Identify goals of phonological skill instruction, know the progression of phonological skill development (rhymes, syllables, onset-rimes, phonemes), principles of phonological skill instruction (brief, multisensory, conceptual and auditory-verbal), understand the reciprocal nature of phonological processing, reading, spelling and vocabulary, and understand how the phonological features of a second language might interfere with English pronunciation and phonics.</p>	<p>This section outlines the standards that refer to teaching systematic phonics and accurate word decoding skills.</p> <p>Recognize how to order phonics concepts, understand explicit and direct teaching, understand multisensory and multimodal techniques, understand lesson format from word recognition to fluent application in meaningful reading and writing, understand research-based adaptations of instruction for students who have weaknesses in working memory, attention, executive functioning or processing speed and the application of the above concepts.</p>
Structured Language Teaching: Fluent, Automatic Reading of Text	<p>This section outlines the standards that refer to teaching systematic phonics and accurate word decoding skills.</p>	<p>Recognize how to order phonics concepts, understand explicit and direct teaching, understand multisensory and multimodal techniques, understand lesson format from word recognition to fluent application in meaningful reading and writing, understand research-based adaptations of instruction for students who have weaknesses in working memory, attention, executive functioning or processing speed and the application of the above concepts.</p> <p>This section outlines the standards that refer to teaching fluency. Underdeveloped or poor fluency is a characteristic of dyslexia and inhibits other reading processing including comprehension.</p>

Understand the role of fluency in reading, that fluency is a stage of normal reading development occurs with practice and may be a symptom of some reading disorders, understand the concepts of frustration, instructional and independent reading levels, what instructional activities are likely to improve fluency, techniques that will assist in reading motivation, and understand the appropriate use of assistive technology and the application of these concepts.

This section outlines the standards that refer to vocabulary and its importance with regard to reading comprehension, in addition to providing teachers information with regard to the importance of vocabulary in reading and listening and how to provide a classroom environment that is rich in access to vocabulary.

Understand the role of vocabulary development and knowledge in comprehension, understand the role of direct and indirect methods of vocabulary instruction, know the techniques used to teach vocabulary before, during and after reading, understand the reasons for the considerable variability in students' vocabularies, and teaching word meaning.

This section outlines the standards that refer to reading comprehension, particularly teaching comprehension and identifying weaknesses that require intervention.

Be familiar with teaching strategies that are appropriate before, during and after reading, contrast the characteristics of major text genres including narration, exposition and argumentation, understand the relationship between text comprehension and written composition, identify potential miscomprehension in text, understand the levels of comprehension including surface code, text base and mental model/situation model, understand factors that contribute to deep comprehension.

(Continued on next page)

Structured Language
Teaching: Vocabulary

Structured Language
Teaching: Text
Comprehension

TABLE 3 Section 1 of the Knowledge and Practice Standards for Teachers of Reading (*Continued*)

Section 1 Knowledge and Practice Standards	
Areas	Examples
<p>Structured Language Teaching: Handwriting, Spelling and Written Expression</p>	<p>This section outlines the standards that refer to handwriting, keyboarding, spelling and written expression, including capitalization and spelling.</p> <p>Know research-based principles for teaching letter naming and letter formation, techniques for teaching handwriting fluency, recognize and explain the relationship between transcription skills and written expression, identify students' levels of spelling development and orthographic knowledge, be able to explain the influences of phonological, orthographic and morphemic knowledge on spelling, understand the major components and processes of written expression and their interactions, know grade and developmental expectations for students' writing and understand appropriate uses of assistive technology in written expression.</p>
<p>Interpretation and Administration of Assessments for Planning Instruction</p>	<p>This section outlines the standards that refer to interpreting and administering assessments for planning instruction. This section includes standards that must be demonstrated for not only the content knowledge and its application, but also competencies for teaching students with dyslexia and related difficulties.</p> <p>Understand the differences between screening, diagnostic, outcome and progress-monitoring assessments, the basic principles of test construction, including reliability, validity and norm-referencing and know the most well-validated screening tests, understand the principles of progress-monitoring and the use of graphs to demonstrate progress, know the range of skills typically assessed by diagnostic surveys of phonological, decoding, oral reading, spelling and writing skills, recognize the content and purposes of the most common diagnostic tests used by psychologists and educational evaluators, interpret measures of reading comprehension and written expression.</p>

**Knowledge of Dyslexia
and Other Learning
Disorders**

This section outlines the standards that refer to understanding the nature of dyslexia and other learning disorders.

Understand the most common intrinsic differences between good and poor readers, the tents of the NICHD/IDA definition of dyslexia, that dyslexia and other reading difficulties exist on a continuum of severity, be able to identify the distinguishing characteristics of dyslexia and related reading and learning disabilities, identify how symptoms of reading difficulty may change over time in response to development and instruction, and understand federal and state laws that pertain to learning disabilities, especially reading disabilities and dyslexia.

Section I standards include knowledge regarding oral and written learning, knowledge of the structure of language, phonology, phonics and word recognition, fluency, vocabulary, comprehension, handwriting, spelling, written expression, assessment for planning instruction, and knowledge of dyslexia and other learning disorders. Section II provides standards related to demonstrating the competency of knowledge and skills that novice teachers must know to teach reading (Level I) and the competencies of knowledge and skills that must be demonstrated for specialists who intend to provide services to individuals with dyslexia and other learning disorders.

Prerequisite knowledge that would be very helpful for pre-service teachers to possess prior to exposure to the knowledge and practice standards (Moats et al., 2010) would include a sequence of coursework that involves research methods, linguistics, cognition and a course outlining the science of reading. Section II of the *Knowledge and Practice Standards* lists practicum experiences that are necessary. If the standards are not used to develop the sequence of courses, then two separate practicum experiences should be included (See Table 5). The rationale for the research methods course is to prepare students in critical thinking with regard to science, to prepare students to understand the technical aspects of the scientific method, design, and analysis issues, and how results and findings are communicated. This course will help pre-service teachers not only understand the process and content of science but provides them with a framework so that they can comprehend the scientific literature regarding reading, which is vast and complicated, as well as digest new findings as they are provided, allowing teachers to maintain current knowledge in reading as well as other subjects once they enter the field. One course will not be the panacea but will begin the process and will help pre-service teachers understand the nature of the science of reading course and to be prepared to engage in the standards outlined in the *Knowledge and Practice Standards*. The research methods course should be demanding and should be a litmus test to some extent for the suitability of the student to be admitted into a teacher education or certification program.

A course in linguistics or psycholinguistics should be the second of three prerequisite courses for the science of reading course. This course will provide pre-service teachers with the nec-

TABLE 4 Section 2 of the Knowledge and Practice Standards for Teachers of Reading

Section 2 Guidelines pertaining to Supervised Practice of Teachers Who Work in School Settings

Level	Description and Requirements
I	<p>Description: This level is intended for novice teachers in training who implement an appropriate program with fidelity, formulate and implement an appropriate differentiated lesson plan, and demonstrate proficiency to instruct individuals with reading disability or dyslexia.</p> <p>Requirements:</p> <ol style="list-style-type: none">1. Pass an approved basic knowledge proficiency exam.2. Demonstrate, over time, instructional proficiency in all Level 1 areas outlined in Table 3 above.3. Document significant student progress with formal and informal assessments as a result of the instruction.
II	<p>Description: This level is intended for specialists who must demonstrate additional expertise and abilities to provide services to individuals with dyslexia and other learning disorders.</p>

(Continued on next page)

TABLE 4 Section 2 of the Knowledge and Practice Standards for Teachers of Reading (*Continued*)

Level	Section 2 Guidelines pertaining to Supervised Practice of Teachers Who Work in School Settings
Level	Description and Requirements
Requirements:	<ol style="list-style-type: none"> <li data-bbox="437 892 456 1468">1. Pass an approved basic knowledge proficiency exam. <li data-bbox="466 244 575 1468">2. Complete a one-to-one practicum with a student or small group of one to three well-matched students who have a documented reading disability. A recognized, certified instructor* provides consistent oversight and observations of instruction delivered to the same student(s) over time, and the practicum continues until expected proficiency is reached.** <li data-bbox="584 378 603 1468">3. Demonstrate (over time) instructional proficiency in all Level 1 and 2 areas outlined in Table 3 above. <li data-bbox="613 274 664 1468">4. Provide successful instruction to several individuals with dyslexia who demonstrate varying needs and document significant student progress with formal and informal assessment as a result of the instruction. <li data-bbox="673 244 724 1468">5. Complete an approved educational assessment of a student with dyslexia and/or language-based reading disability, including student history and comprehensive recommendations.

Note. * = A recognized or certified instructor is an individual who has met all of the requirements of the level they supervise but who has additional content knowledge and experience in implementing and observing instruction for students with dyslexia and other reading difficulties in varied settings. A recognized instructor has been recommended by or certified by an approved trainer mentorship program that meets these standards. The trainer mentorship program has been reviewed by and approved by the IDA Standards and Practices Committee.

** = Documentation of proficiency must be: (a) completed by a recognized/certified instructor providing oversight in the specified program; (b) completed during full (not partial) lesson observations; and (c) must occur at various intervals throughout the instructional period with student.

TABLE 5 Potential Required Courses to be Included in an Elementary Education Program to Promote the Science of Reading

Course Title	Course Content
Research Methods	Basics of scientific principles
Linguistics/Psycholinguistics	Introduction to linguistics.
Cognition	Introduction to cognitive sciences, which would include empirical methods, models, and data.
Science of Reading	See Table 4.
Science-based Reading Evaluation and Interventions	Theoretical basis of assessment instruments and their results in addition to developing individualized interventions based on assessment protocols.
Practicum in Reading I	Evaluation of reading and comprehension utilizing phonological processing, phonics, fluency and vocabulary. Develop strategies to assist in the development of reading acquisition.
Practicum in Reading II	Evaluation of reading and comprehension in struggling readers utilizing phonological processing, phonics, fluency and vocabulary. Develop strategies to assist in the development of reading acquisition.

essary knowledge and understanding concerning language and its subparts. The course should provide detailed exposure to phonology, phonetics, morphology, syntax, semantics, and grammar. This information is vital to prepare the student to embrace the concepts that will be presented in the science of reading course.

The third prerequisite course for the science of reading course should be a foundational course in cognition. The main reason that this course should be included involves preparing students for the content of the science of reading course, much of which will require familiarity with concepts developed in the cognitive sciences. It will be important for pre-service teachers to have a conceptualization of the models and theories, as well as the methods used to create the models and theories. The topics should include attention, memory, perception, language, and metacognition. The intention of the three prerequisite courses would be to prepare pre-service teachers for the content that will be covered in the science of reading course.

TABLE 6 Potential Content for a Science of Reading Course Designed for Undergraduate Pre-Service Teachers

Course Content

Writing Systems
Alphabetically-Based Writing Systems
History of English Writing System
Orthography
Languages that contributed to the English Writing System
History of Teaching Reading 1880 to present
Mechanics of English Writing System
Letter-Sound Correspondence
Phonics
Visual Processing and Reading
Phonology and Phonological Processing
Lexical Access
Fluency
Morphemes and Syllable Structure
Interdependence of Phonological Processing, Fluency, and Vocabulary
Comprehension
Literacy
Assessment of Dyslexia and Reading Difficulties
Interventions for Dyslexia and Reading Difficulties
The Role of Attention in Reading
Attention Deficit Hyperactivity Disorder
Appropriate assessment
Potential interventions
The Effect of ADHD on Reading

The science of reading course (see Table 6) itself should provide a comprehensive examination of writing systems with particular emphasis on the English writing system, how the English writing system developed, and the influences from other languages, an examination of the history of teaching reading, and the mechanics of the English writing system. It will be important to expose pre-service teachers to the science-based theories regarding reading, including visual processing theories and the influence of phonology and phonological processing in reading acquisition. Additional information regarding lexical access, fluency, morphemes, and syllable structure beyond what was covered in the linguistics course as it applies to reading should be included. Information concerning the interdependence of

phonological processing, fluency and vocabulary, how readers gain in each by development of the others, and how these abilities lead to comprehension should be presented and discussed along with issues relevant to literacy. Most importantly, the concepts presented in this course should be applied to reading acquisition, development, and maintenance. It will be necessary to present pre-service teachers with an introduction to assessment and how assessment devices are used to identify beginning readers who are having difficulty acquiring the various subtasks involved in reading acquisition. Pre-service teachers also need to be presented with strategies and interventions designed to improve specific subskills that were identified as weak in the student who is experiencing reading failure. Lastly, the interdependency of attention and the reading process should be addressed along with how interventions can assist with reading development with students who are experiencing attentional difficulties.

There are numerous other topics that could be presented, but the science of reading course should be a blueprint for developing specific courses designed to assist pre-service teachers to acquire the necessary knowledge and skills that will help to increase reading proficiency in their students. However, it is very difficult to provide interventions for students who are failing reading acquisition if the teacher does not have a concept of a phoneme, how to help students discern that phonemes are represented by letters, that words are comprised of phonemes, how to decode letters into their various sounds, and to engage in phonemic synthesis. These are necessary skills for pre-service teachers to have, but many currently do not have this knowledge and are unlikely to divine them without explicit instruction via coursework.

The first practicum course would involve examining various evidence-based strategies to identify strengths and weaknesses in students' reading skills. After initial discussion of these assessment tools, students would then practice using them with students at their practicum site—an elementary school. Pre-service teachers should also be presented with evidence-based strategies to improve reading and its subskills. Once the child's strengths and weaknesses have been identified, interventions would then be applied to strengthen the skills that were identified as weak and to further strengthen the skills that have been appropriately developing. Pre-service teachers should be observed and provided

on-going feedback regarding their performance with these interventions, how to determine when an intervention is working, and what mechanisms could be applied to modify an intervention to make it success for a particular student.

The second practicum course would specifically address the needs of students who have been identified as having dyslexia or reading difficulties. It is important that pre-service teachers have experiences with students who are experiencing reading failure so that they can directly witness how the strategies learned from their reading intervention components can be applied to help students become competent readers. It is through these experiences that pre-service teachers will learn to apply their knowledge of the science of reading and to discover how the science of reading can be used to develop their skills to teach the whole classroom as well as help students who are experiencing reading failure. It is likely that the knowledge and skills learned through the practicum courses can then be presented to seasoned teachers who did not receive this type of training while they were students themselves via professional development.

The sequence of courses outlined above could be used as a demarcation point for discussion of how best to train pre-service teachers in the science of reading. *The Knowledge and Practice Standards* very clearly point out the knowledge and skills that are necessary to be specifically comprehended and mastered for teachers of reading and those who will provide interventions for students who are experiencing reading failure. Without this knowledge, the status quo of continued poor reading skills will continue.

The science of reading contains a corpus of knowledge regarding the likely causes and interventions for improving reading skills for students who are experiencing reading failure. Insuring that pre-service teachers are competent in applying their knowledge of the science of reading is critical in reducing reading failure and poor performance in reading. It is imperative that colleges of education examine their coursework and either adopt a strategy as outlined in this study or modify their coursework to include evidence-based courses that will present pre-service teachers with the knowledge and skills that will allow them to assist their students to become competent readers. The results of the present study indicate that pre-service teachers possess the skill that will allow them to become competent teachers of reading and

interventionists for struggling readers if they are trained to become competent in the science of reading.

Notes

1. The term the “science of reading” refers to the corpus of knowledge that includes what science has determined to be relevant to reading, reading acquisition, assessment of poor reading, and the interventions available for poor readers. The science of reading involves precisely what science has discovered to be relevant not only to reading, its subskills, and reading acquisition but how to modify experiences such that poor readers can become competent readers. This knowledge includes phonology, phonics, orthography, fluency, vocabulary, comprehension, neuro-processing as it relates to reading and its genetic basis, visual, perceptual and memorial processing, the various writing systems, the alphabetic principle, and letter-sound correspondences, among other areas.
2. The data were also evaluated with multivariate analysis of variance with the same results.

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