PREDICTIVE RELATIONSHIPS BETWEEN PHONEMIC AWARENESS, VERBAL SHORT-TERM MEMORY, AND WORKING MEMORY WITH SPELLING ACHIEVEMENT AMONG GRADE 1 STUDENTS AT THAI CHRISTIAN SCHOOL, THAILAND

Andrew James Wixey

A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of MASTER OF EDUCATION in Curriculum and Instruction Graduate School of Education ASSUMPTION UNIVERSITY OF THAILAND 2016
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ABSTRACT

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This research investigates spelling achievement along with the ability to recognize sounds in words and the capacities to temporarily store and manipulate information in memory. The aims were to determine the levels of phonemic awareness, verbal short-term memory, working memory, and spelling achievement among 114 grade 1 students at Thai Christian School; then, to investigate if there was a predictive relationship with spelling achievement. The level of phonemic awareness was much lower (3rd percentile) than U.S. first grade students (Cummings, Otterstedt, Kennedy, Baker, & Kame’enui, 2011); verbal short-term memory and working memory levels were average; and spelling achievement was in the early to middle stage of letter name-alphabetic spelling, within the expected range for students in kindergarten through to the middle of second grade. A multiple regression analysis found
significant positive predictive relationships between phonemic awareness, verbal short-term memory, and working memory with spelling achievement. Spelling achievement findings closely aligned with a developmental model, but students had a wide range of abilities, suggesting a differentiated spelling program based on developmental stages could be beneficial. Recommendations include a direct focus on teaching phonemic awareness skills as well as providing further practice with early spelling features, specifically the need to master final consonants and short vowels. Further research could be done to improve the prediction of spelling achievement by including other measures linked to literacy, such as letter-sound knowledge.

Field of Study: Curriculum and Instruction
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CHAPTER I

INTRODUCTION

This chapter presents the background of the study, statement of the problem, research questions, research objectives, research hypothesis, theoretical framework, conceptual framework, scope of the study, definitions of terms, and significance of the study.

Background of the Study

Spelling is certainly not a new topic – the first alphabet-based writing system is around 3,600 years old (“Sinaitic inscriptions,” n.d.) – yet it is still an especially challenging task for young students who are on the path to literacy (Gurney-Read, 2015).

Students’ spelling achievement depends on learning knowledge about spelling that must also be applicable to unfamiliar words (Kingsley, 2012): phonemic awareness is required in order to manipulate sounds and spell (Ebert, 2009).

Information storage and manipulation - such as the word being spelled and knowledge of spelling features - falls under the domain of memory. The demands of spelling appear to make use of verbal short-term memory for maintaining sounds in temporary memory and learning a new language; words that are read are subvocalized and processed in the same way as when listening to words. A general memory resource shared by many tasks is working memory; it is required when dealing with challenging situations requiring attention such as spelling an unfamiliar word, which is a complex process that involves combining lexical and sublexical knowledge to
construct a representation of the word (Alloway & Alloway, 2010; Baddeley, 2007; Rapp, Epstein, & Tainturier, 2002).

**Spelling in Schools**

Firstly, spelling is not the same in schools around the world because it depends on the language, which in this case is English. Unfortunately for students, English is a complicated language when it comes to spelling, particularly as there are different spellings of the same sounds and many foreign words that have been integrated into the language over the years.

There are a wide variety of approaches to spelling including the use of phonics, spelling programs, and lists derived from other sources such as reading programs. However, there are divided opinions about teaching spelling. Some schools no longer teach spelling as a specific part of lessons and may instead teach spelling skills through other reading and writing activities. In the USA, where spelling bee competitions are common, teaching spelling in schools has at times been controversial: some say it is stressful for students and that the rote memorization involved is not useful, while others point to falling literacy standards to promote its importance. Another problem with teaching spelling is that the methods used may not be good, especially in the past, which is likely to still affect the approach used by current teachers (Gentry, 2011; Schlagal & Trathen, 1998).

**Spelling in Thai Christian School**

Weekly spelling words has been an important part of the Grade 1 English program at Thai Christian School. Each week students were introduced to 10 words, of which 3 were short phonics words taken from their textbooks, *Phonics Fun 1 & 2*
(Bunton, 2003) or *English World 1* (Bowen & Hocking, 2009); 3 common words from the top 200 high-frequency words in phases (Department for Education and Skills (England), 2007); and 4 vocabulary words related to the theme of a unit in *English World 1*.

A typical week of spelling involves students being introduced to the words via PowerPoint, then writing them in a booklet to learn for homework; words are also reviewed in class during the week. The class plays some spelling games and uses a cover-copy-compare method of writing practice. A spelling test is given with an extra 5 review words from the previous two weeks. A marking scheme of 0 - 4 points per word is used to acknowledge the degree of correctness.

The background of Thai Christian School, the English curriculum, and spelling program is discussed in greater detail in Chapter II.

**Statement of the Problem**

This section describes the main issue of spelling achievement, and how phonemic awareness and memory may be relevant.

The Grade 1 spelling program has appeared to be successful for the majority of students in previous years and improved by the current system, however, up to the present year, the focus has mainly been on two aspects: providing an opportunity to practice a phonetic approach to spelling and learning words that will be used when writing sentences in their English books. With a class size of around 30 students, teachers have relied on whole-class direct instruction through a more teacher-centered approach. However, it may not address the needs of some individual students as well as spelling programs which require differentiated group work. A further issue is that trying to integrate spelling with the course textbooks partially
determines which words are included and at what time, so (1) there may be a lack of consistency week-to-week, and (2) the words may include spelling features which have not been studied and may not be suitable for studying until they are older, thus students may have to rely on memorization instead of applying spelling knowledge.

A pre-test and post-test were introduced this year to better monitor students' improvement with spelling, but the words on the test are from the weekly word lists and therefore subject to the same issues described above.

The teachers encourage students to try to sound out words when they are not sure about the spelling and remind them they can get some points for a word even if it is not fully correct. The motivation for choosing the marking scheme of 0 to 4 points for a word was to encourage students to always try to spell a word, even if they are uncertain. This touches on the idea of invented spelling, although, in daily writing, students instead tend to look up words in their books; this can be slow and may not encourage development of spelling skills.

As part of learning letter-sound correspondence in phonics classes, the students need phonemic awareness to be able to distinguish between the different sounds in words and manipulate them (Ebert, 2009). Some students appear to struggle to recognize sounds correctly and use phonetic spellings.

Many students scored highly on their weekly spelling tests, but pre-tests and post-tests seemed to show a greater spread of results. There was a minority of students who performed poorly on both and seemed to struggle to make significant progress. Students should also learn the spelling words for homework and so parental involvement or other outside support may be an important aspect - some students do make improvement after their teacher communicates about the issue, although this
may only reflect more time spent memorizing whole words, with little understanding of individual spelling features.

One mechanism that might explain a student's level of academic achievement is their memory. The author is curious how students' abilities to both temporarily store and process information may predict their spelling achievement, as the limitations of capacity and time for short-term memory have been compared to a "bottleneck for learning" (Gathercole & Alloway, 2006, p. 6). This could affect how well students are able to both acquire knowledge relevant to spelling and be able to utilize it to spell more challenging words. Short-term and working memory capacity have been shown to increase with age until the late teens or adulthood, but the increases appear to be relative to individuals and therefore a stable measure which has been researched as an alternative to IQ in predicting achievement in literacy and numeracy. Grade 1 is an interesting and important age to study the involvement of memory for two reasons: (1) Sufficient practice makes it possible to recall words automatically from long-term memory, but Grade 1 students are still very young and have not had much time to build up a large vocabulary, so they may need to rely more on applying knowledge which would require a greater reliance on working memory. (2) It is important that all students make the best progress they can and acquire a wide range of basic skills - including spelling - to be able to do well in higher grades, so it would be beneficial if Grade 1 students at risk of making slow progress could be given extra support and monitored closely from an early stage.

There is a general lack of research into English spelling in Thailand with young bilingual learners. The author hopes to contribute to this field by producing research that can be useful for further research or teachers in other schools.
The researcher wished to know: Are Grade 1 students at Thai Christian School developing useful knowledge about spelling which can be applied to unfamiliar words? How important for spelling is being able to recognize the separate sounds in a word? Is spelling dependent upon the capacity to hold words and sounds in mind and process relevant information?

**Research Questions**

This research aims to establish answers to the following questions:

1. What is the level of phonemic awareness of Grade 1 students at Thai Christian School?

2. What is the level of verbal short-term memory of Grade 1 students at Thai Christian School?

3. What is the level of working memory of Grade 1 students at Thai Christian School?

4. What is the level of spelling achievement of Grade 1 students at Thai Christian School?

5. Is there a positive predictive relationship between phonemic awareness, verbal short-term memory, and working memory with spelling achievement of Grade 1 students at Thai Christian School?

**Research Objectives**

1. To determine the level of phonemic awareness of Grade 1 students at Thai Christian School.

2. To determine the level of verbal short-term memory of Grade 1 students at Thai Christian School.
3. To determine the level of working memory of Grade 1 students at Thai Christian School.

4. To determine the level of spelling achievement of Grade 1 students at Thai Christian School.

5. To determine if there is a significant positive predictive relationship between phonemic awareness, verbal short-term memory, and working memory with spelling achievement of Grade 1 students at Thai Christian School.

**Research Hypothesis**

There are significant positive predictive relationships between phonemic awareness, verbal short-term memory, and working memory with spelling achievement of Grade 1 students at Thai Christian School such that the higher their phonemic awareness, verbal short-term memory, and working memory, the higher will be their spelling achievement.

**Theoretical Framework**

This research is based on developmental stages of spelling, a hierarchy of phonological awareness tasks, a model of working memory, and cognitive architecture of spelling.

**Developmental Stages of Spelling**

The way in which students make progress towards becoming proficient spellers can be described in terms of developmental stages. Bear, Invernizzi, Templeton, and Johnston (2012) described five developmental stages of spelling. These stages are not fixed to specific ages and have some overlap, but they identify
the extent of students' understanding of spelling. Grade 1 learners are likely to operate within the three earlier stages: (1) emergent spelling - students may memorize some short words and include some phonetically correct letters in words; (2) letter name-alphabetic spelling - students rapidly develop phonetic knowledge to be able to write initial and final consonant sounds, single-syllable words, partially correct long vowel sounds, some consonant blends, and possess an enlarged repertoire of common words that can be spelled from memory; and (3) within word pattern spelling - students learn to use both sound and patterns of spelling, particularly patterns of vowels, and begin to consider meaning to distinguish between homophones.

This stage model described by Bear et al. (2012) provides a clear framework for assessing spelling achievement (SA) in a manner that does not rely on just rote memorization of words.

**Hierarchy of Phonemic Awareness Tasks**

Adams (1990) described phonemic awareness as the capacity to recognize - requiring a conscious effort - that a spoken word is composed of distinct sounds smaller than a syllable (i.e., phonemes) which can be separated and altered to form new words. Adams classified phonemic awareness tasks into five categories of increasing difficulty: (1) saying nursery rhymes, (2) identifying similar and dissimilar sounds, (3) blending phonemes to form words and splitting words into syllables, (4) segmenting words into phonemes, and (5) manipulating phonemes by adding, removing, or reordering phonemes to form new words. A suitable phonemic awareness (PA) task can be selected on the basis of this hierarchy.
Working Memory and the Phonological Loop

There are some discrepancies among various models of memory, but the working memory model proposed by Baddeley and Hitch in 1974 has relevance as it has been supported by research specifically with children (Alloway, Gathercole, & Pickering, 2006). It was originally comprised of three components, with a fourth component added by Baddeley in 2000, all of which have limited capacities (Baddeley, 2000, 2007).

The components of the model are (1) the central executive - a system which controls the three other systems and is responsible for attention and processing in complex non-routine tasks, (2) the phonological loop - a system for temporary storage of phonological information, assisted by a rehearsal mechanism, (3) the visuospatial sketchpad - a system for temporary storage of visual and spatial information, which provides visuospatial short-term memory, and (4) the episodic buffer - an additional temporary storage system which allows for integration between the other systems and long-term memory. A diagram of the working memory model is shown in Figure 1.

In addition to describing working memory, this model gives an account of the manner in which the phonological loop is responsible for verbal short-term memory (VSTM) and justifies the different types of tasks required to separately assess VSTM and working memory (WM).
Figure 1. Working memory model. The relationships between working memory, short-term memory, and long term memory, adapted from Baddeley (2000).

Cognitive Architecture of Spelling

To have a better understanding of the significance of working memory in the spelling process, it is necessary to have some insight into what types of processing demands are placed on it.

Rapp, Epstein, and Tainturier's (2002) model of the cognitive architecture of spelling describes dual processing tasks that utilize long-term memory of words, as well as non-word sound information. This goes through a final maintenance and processing phase to piece together the correct spelling. The model is discussed in more detail in Chapter 2.

Theoretical Framework Summary

This research is based upon four theories. The developmental stages of spelling described by Bear et al. (2012) explain stages involved in learning to spell.

**Conceptual Framework**

The aim of this study is to assess the phonemic awareness, verbal short-term memory, working memory, and spelling achievement of Grade 1 students at Thai Christian School to determine if there are significant predictive relationships with their spelling achievement. The conceptual framework for the variables is shown in Figure 2.

![Conceptual Framework Diagram](image)

**Phonemic Awareness (PA)**
Phoneme Segmentation Fluency (Good & Kaminski, 2002)

**Verbal Short-Term Memory (VSTM)**
Digit Span Forward (Wechsler, 2003)

**Working Memory (WM)**
Digit Span Backward (Wechsler, 2003)

**Spelling Achievement (SA)**
Primary Spelling Inventory (Bear, Invernizzi, Templeton, & Johnston, 2012)

*Figure 2. Conceptual framework. The conceptual framework for the predictive relationship between PA, VSTM, and WM with SA, and the respective instruments.*

The framework does not control for any other variables, although there are other factors which are likely to have some influence on spelling achievement which include intelligence, reading ability, different teachers and extra tuition, the first language or languages spoken at home, and the level of parental involvement.
Scope of the Study

Four variables are measured: (1) students' understanding of the sounds of which words are comprised - PA - assessed with a spoken Phoneme Segmentation Fluency task (Good & Kaminski, 2002); (2) temporary storage of verbal information - VSTM - assessed with verbal recall of number sequences on a Digit Span Forward task (Wechsler, 2003); (3) temporary storage and manipulation of information - WM - assessed with verbal recall of numbers in reverse order on a Digit Span Backward task (Wechsler, 2003); and (4) achievement on a spelling test - SA - assessed with written answers to the Primary Spelling Inventory (Bear et al., 2012). This data is used to investigate predictive relationships between the independent variables PA, VSTM, and WM with the dependent variable SA.

The study is limited to Thai Christian School, which is a private school in Bangkok. It included all 114 Grade 1 English Program students in the second term of the 2015-2016 academic year.

One potential limitation of the study is that each of the four Grade 1 classes had a different homeroom teacher who may be more or less effective than the others with spelling instruction. However, trying to control for the effect of different teachers may not be meaningful since it is unlikely that each class was assigned students entirely at random at the beginning of the year and therefore also unlikely that the mean spelling achievement was the same from the start. The effect of having different teachers may have been reduced by the teachers following the same lesson plans and using the same teaching materials.

Definitions of Terms

The following terms are defined for the context of this thesis.
Dependent Variable

**Spelling Achievement**: performance on the Primary Spelling Inventory (Bear et al., 2012) which is a test for kindergarten to third grade students consisting of 26 words. Students were tested as a whole class by having each word read aloud for them to write down the spelling. Interpretation of the level of performance is based on (1) points scored for spelling features, which relate to specific stages of development, and (2) the number of correctly spelled words. Spelling achievement is determined by the total score of feature points and correct words.

Independent Variables

**Phonemic Awareness**: a student's ability to distinguish and manipulate the shortest units of sound of which spoken words are comprised. This was assessed using a 1 minute long Phoneme Segmentation Fluency task (Good & Kaminski, 2002) where points were scored for each correct segment of verbally presented words.

**Verbal Short-Term Memory**: the capacity to store phonological information for a brief period of time while in use. This was assessed by individually administering a Digit Span Forward task (Wechsler, 2003) whose score depended on the number of spoken sequences of digits of increasing length which could be repeated.

**Working Memory**: the capacity to simultaneously store and process information for a brief period of time while in use. This was assessed by individually administering a Digit Span Backward task (Wechsler, 2003) which was similar to the forward task, except that the repeated digit order had to be reversed - last to first.
Other Terms

**Thai Christian School**: a medium-sized private school in central Bangkok with an English program taught by native speakers. Most students have Thai nationality. This research was done with 7-year-old students at the end of grade 1.

**Significance of the Study**

The immediate usefulness of this study will be to apply the findings of this research to improve the planning and delivery of spelling instruction in Grade 1 at Thai Christian School to take into account the strengths and weaknesses identified in spelling achievement, phonemic awareness, verbal short-term memory, and working memory. This study was the first use of these research instruments at Thai Christian School, which could prove to be useful in the future for supporting students with spelling achievement.

This study should contribute towards remedying the lack of research into English spelling in Thailand with young bilingual learners and should provide data on the range of PA and memory capacities which may be encountered in a class. Other teachers and researchers may be able to make use of the findings as the instruments are not specific to the curriculum at Thai Christian School.

**Summary**

This chapter looked at the background of spelling in schools, which can greatly vary. Problems were discussed relating to spelling achievement, and the relationship between spelling, phonemic awareness, and memory. Five research questions and research objectives were stated, along with one hypothesis. A summary of the theoretical framework was given which included developmental stages of
spelling, a hierarchy of phonemic awareness tasks, and a model of memory. The relationship between the variables was illustrated in the conceptual framework and the scope of the study was discussed in relation to Grade 1 at Thai Christian School. The definitions of terms were given for the context of this research and the significance of the study was examined in terms of improvement of spelling instruction and improving upon a lack of research in this specific area. This research investigated spelling of first grade students and examined to what extent levels of phonemic awareness, verbal short-term memory, and working memory could predict spelling achievement.

The following chapter reviews literature related to the main topic of spelling and how it develops, ability to hear and manipulate sounds in words, a form of short-term memory which is dedicated to sounds, and the more general working memory. Previous studies of spelling achievement and connections with phonemic awareness and memory are examined. More detail is provided about Thai Christian School and the Grade 1 spelling program.
CHAPTER II

REVIEW OF RELATED LITERATURE

This chapter presents a review of literature on spelling, phonemic awareness, memory, related research, and the background of Thai Christian School.

Spelling

The English system of spelling is challenging even for native speakers, with students requiring as much as two years longer than students of other European languages to attain basic literacy skills. Although there are those who seek to offer a simpler spelling system, students need to be prepared for the present situation which is likely to remain the same for the foreseeable future (Gurney-Read, 2015).

Given the difficulty of English spelling, one might assume that a high priority would be given to this topic in all schools, but there have been movements away from spelling, where less emphasis may be placed on memorizing words and more on meaning. This approach may mean some schools abandon spelling tests altogether, but one consequence can be that students struggle to spell words several grade-levels below their actual grade (Gentry, 2011). Other reasons for abandoning spelling tests have been that students may find the tests stressful (“Pupils ‘distressed over spelling,’” 2008) and teachers' preferences for incidental teaching even though this approach was not backed by research (Mayer & Alexander, 2011).
Teaching Spelling

Two slightly different challenges that students may face in day-to-day writing are the spelling of words with which they are at least somewhat familiar and those which are completely new to them. Thus, learning to spell requires both memorization of words and also the development of skills to tackle the unknown (Invernizzi & Hayes, 2004).

**Ineffective Strategies.** One of the least effective strategies associated with teaching spelling is having students simply copy a list of words multiple times: one reason this is ineffective is the lack of error-checking done by the student, with the potential to make an error when copying and learn an incorrect spelling (T. B. Mann, Bushell, & Morris, 2010).

Fitzsimmons and Loomer (as cited in Wallace, 2006) identified additional ineffective strategies employed by teachers: overdependence on phonics, introducing spelling words already in a sentence, and having students find their own method of learning the words.

**Effective Strategies.** A straightforward amendment to the procedure of copying lists of words is the cover-copy-compare method wherein students may first write the word while looking at it, then they must cover it and try to reproduce the spelling from memory, then compare the spelling: this provides immediate corrective feedback to the student. A second strategy that may be taught, sounding out, can be combined with cover-copy-compare to improve spelling. Sounding out can be effective for students that have already developed phonetic knowledge of letter sounds (T. B. Mann et al., 2010). A similar approach is look-say-cover-write-check (and repeat if incorrect) (Wallace, 2006).
Direct instruction plays a vital part in the teaching of spelling skills, particularly providing logical progression of words to be learned, review, regular practice (which is often overlooked), and correction of errors. Phonics is one of the most important teaching tools available for boosting spelling skills, as indicated by a meta-analysis of almost 2,000 research papers on PA (Simonsen & Gunter, 2001). However, it would be a mistake to only teach phonics, since many frequent words cannot be spelled that way: the whole-word approach may require students to memorize entire words, but students can be explicitly taught to break the word into parts that may be more easily remembered in combination with phonetic skills. Simonsen and Gunter also proposed that error correction by the teacher, as well as being more effective than student self-discovery of errors, is a teaching opportunity: correcting errors can be done through circling mistakes or verbal prompts that do not simply provide the correct answer, but require students to correct mistakes themselves. In order to be able to do this, students need explicit phonics instruction to learn about letter sounds in all positions of the word, rather than focusing on initial sounds in the case of implicit phonics teaching (Jackson, 2006).

**Differentiation.** One problem with spelling is the list of words to be learned. There is a significant amount of research on the topic of differentiating spelling instruction to the level of the student. Schlagal and Trathen (1998) attributed success of differentiation to enabling less able spellers to learn words of appropriate difficulty which they are then able to use. Invernizzi and Hayes (2004) cautioned that while pair or group work is necessary for differentiation, it is only recommended as a student-led follow-up to whole-group teaching rather than for the teacher to exclusively instruct small groups.
**Authentic learning.** One strategy which may be effective, but by its nature is difficult to assess, is *incidental spelling*. Word lists are based on words that students encounter in the classroom, such as in a thematic unit of study, with the reasoning being that the students would be more motivated to learn the words.

Teaching spelling through reading and writing is important, but it is advisable to also include a structured list such as one based on sight words. The words to be learned will not be effectively practiced if they are only used in the context of spelling instruction (Wallace, 2006).

**Non-native English learners and spelling.** The extra challenge of spelling in another language is one that needs to be accommodated by the teacher through methods that enable students to learn the meaning, such as using multimedia, and linking speech with words by highlighting them (Bengochea, 2014).

Although there are substantial differences between Thai and English – not only the alphabet but also phonological differences such as *th*, *sh*, and final consonants *p*, *t*, and *k* (Kanokpermpoon, 2007) – the situation is positive: there is evidence that improvement in PA and reading in Thai can transfer to improvements in English and vice versa (Wei, 2005).

**The Relationship of Spelling to Reading**

Bear et al. (2012) cited a number of studies that found significant correlations between spelling and reading skills, studies that showed spelling could be used to predict reading ability in first to third grade students to a greater extent than reading readiness tests, and that spelling is also a better predictor of current reading ability than PA; similar relationships were also found as early as kindergarten (National Institute for Literacy, 2008). The authors also noted an important finding by
Perfetti in 1997 was that the relationship between spelling and reading is not equal: reading will not develop students' spelling as much as spelling will help students to read better.

Invernizzi and Hayes (2004) suggested that the development of reading, writing, and spelling skills are all interconnected through the student's vocabulary size, which grows rapidly once their skills have developed to the point of independent reading. Pollo (2008) found that, even with emergent spelling, students are already applying patterns to their seemingly random writing of letters that are consistent with statistical properties of text they have seen.

Developmental Models

Spelling is considered a developmental process as students have been observed to transition from phonetic approaches which only require knowledge of letter-sound correspondence, through to spelling within a grammatical context, which in itself requires involves progression: recognizing that some words are not spelled phonetically, that there are conventional spelling patterns, when spelling patterns apply, and when there are exceptions to rules. The difficulty of spelling a word can be considered as the complexity of its spelling features and the extent of spelling development required to understand them (Nunes, Bryant, & Bindman, 1997).

A developmental model of how students spell was developed by Edmund Henderson in 1981 and revised in 1990 and was the basis for the five stage model covering preschoolers to adults described by Bear et al. (2012). The developmental stages are characterized as much by predictable types of mistakes as by correct spelling. Students transition through stages as they gain knowledge of letter-sound correspondence, letter patterns, and meaning, but transitions are gradual (stages
overlap) and students still make use of strategies learned in earlier stages. An overview of the stages is shown in Figure 3.

<table>
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<th>Grade Level</th>
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<tr>
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Figure 3. Developmental stages of spelling. The approximate grade level range associated with each spelling stage; features within the first three stages are also listed. Adapted from Bear et al. (2012).

Stage one is emergent spelling: students may be up to five years old, but nonreaders in Grade 1 could also fit into this category. The stage involves movement away from scribbled writing which is indistinguishable from drawings, to separation of attempted writing and pictures, and finally to recognizable letters - although they do not yet match phonetically. By the end of the stage, students may write a small number of short words from memory.
Stage two, letter name-alphabetic spelling, occurs during the early years of schooling – to the age of 8 – during which students make rapid progress: (1) Initially students use the names of letters to spell words in a partially phonetic manner, thus letter R could represent the word are, and students may make similar substitutions within words to represent sounds; students are likely to only spell initial and final sounds; difficulties exist in distinguishing between letters formed with similar mouth shapes such as B and P; blended letters are partially represented; and there are usually no spaces between words. (2) By the middle of this stage, students are able to write the correct initial and final consonants of words and are making progress on vowels - short vowel sounds may be used incorrectly and long vowel sounds may be represented with unconventional spelling; blends such as bl and digraphs such as sh are identified; and students are able to combine this knowledge to spell words of one syllable, hence, they are now phonetic spellers. (3) By the end of this stage, students are mastering phonetic spelling and making progress with long vowels; a specific indicator that students are in this final section of the stage is the inclusion of the preconsonantal nasal sounds m and n in words like lamp and think which earlier spellers may spell as lap and thik.

Stage three, within word pattern spelling, typically age 7 to 10, is a longer transitional phase from a phonetic approach to one combined with knowledge of how letters are often grouped together. The beginning of this stage coincides with the ability to read independently and is relatively long due to the many alternative spellings of long vowel patterns. Students begin to concentrate more on the meaning of the words they spell, as in the case of homophones – words that sound the same but are spelled differently.
Stage four, syllables and affixes, for students aged 9 to 14, represents a
time of learning to spell longer words through advanced knowledge of syllables,
doubling consonants, and adding prefixes or suffixes to base words.

Stage five, derivational relations, may occur as early as age 9 but it is a
lifelong process. Students learn how related words share common spelling roots and
how to generate the spelling of a word from their existing knowledge.

An example of the transition between these stages is a case where first
grade students were found to mostly rely on sounding out words in order to spell them
(stage two) whereas second grade students used their knowledge of words (stage
three) (Langenthal, 2004).

Bear et al. (2012) stressed that the developmental stages are not defined by
sudden changes but in a qualitative shift towards application of more advanced
knowledge of spelling, even if this may not always be applied correctly. Also, it does
not mean that previous spelling strategies will be abandoned, instead, they will be
integrated. Students can be described as being in an early, middle, or late part of a
stage and that the difference between the late part of one stage and the early part of
the next stage are distinctive but not striking.

Other important developmental findings have been that young students
may incorrectly revert to previous spelling strategies when trying to spell a difficult
word and may try to apply rules beyond their scope, as in the case of adding -ed to
words other than verbs when using the past tense (Critten, Pine, & Steffler, 2007)
which Bear et al. (2012) referred to as "using but confusing" (p.13).

Rittle-Johnson and Siegler (1999) described somewhat different findings
that, through application of the overlapping waves model, explained observed spelling
behaviors. They proposed that students do not simply move from one stage to another,
they make choices between a range of strategies and the frequency with which they choose a strategy will gradually alter, leading to a shift in preferred strategies over time. An analogy would be that acquiring spelling strategies is akin to filling a box with tools: more than one tool might be used for a task, but a choice needs to be made. Their study found that the average number of strategies employed in spelling was three in grade 1 and more than four in grade 2, thus the two different grades were not described by two separate stages, as the students used some of the same strategies. The method used by Rittle-Johnson and Siegler of questioning students about their spelling strategies would be problematic with students whose first language is not the same as the researcher's.

Students that are weak at spelling may fail to apply many strategies, instead relying on sounding out. This was the case with Kieser's (2000) study of 8 first grade students who seemed to rely on the sounding-out strategy that they encountered frequently in their reading program, rather than others taught during the relatively short times of spelling instruction.

**Cognitive Architecture of Spelling**

The mental process of hearing a word and then spelling it is surprisingly complex. Models have been developed that try to account for observed types of spelling errors which began in patients following a brain trauma; this knowledge can be used to infer knowledge of different functions of the components that together form the cognitive architecture responsible for spelling. Generally, it is considered that there are two different processing routes, the first is for recalling word-level information and is referred to as lexical, whereas letters and letter-combinations are referred to as sublexical, since they are shorter than words; spelling any word appears
to involve both routes operating in parallel (Roux & Bonin, 2009). One model (Rapp et al., 2002) expanded on this idea of dual routes by allowing for the contribution of one route to affect the other through a feedback loop. An example with the word *yacht* is shown in Figure 4.

Figure 4. Cognitive architecture of spelling. The figure illustrates the spelling of the word *yacht*, involving dual routes and a feedback mechanism, adapted from Rapp et al. (2002), and Roux and Bonin (2009).

In Figure 4, the sublexical route is on the right and involves the direct conversion of sounds to letters to generate a phonetic spelling. The lexical route, on the left, can generate the spelling of familiar words. Both routes integrate at the
grapheme stage, which can then be followed by written or spoken production of the word's spelling. However, during the final stage of spelling, representations of letters need to be held in memory while feedback helps to form the correct spelling in the correct order (Costa, 2010; Hillis, 2015; Rapp et al., 2002). This maintenance phase is also referred to as a graphemic buffer, or orthographic working memory, due to the processing demands.

**Spelling Assessment**

Robert Schlagal described the spelling errors that students make as being dependent on spelling ability: good spellers make errors that tend to be consistent, whereas weaker spellers' mistakes are characterized by a lack of consistency (Invernizzi & Hayes, 2004). Assessment can be as simple as correct or incorrect, or, complicated enough to require computer analysis of the way a student represented parts of a word and combined them. For young children, correct/incorrect is inappropriate as they may not spell any words entirely correctly (Puranik & AlOtaiba, 2012).

One of the simpler scoring systems (V. A. Mann, Tobin, & Wilson, 1987) uses a scale with a maximum score of 4 points based mainly on the correct representation of phonemes (distinguishable sounds). Points are awarded as follows: zero points if no part (sound) of the word is represented, half a point for one letter representing a correct sound if it is not the initial letter or one point if it is the first letter, two points for two or more letters, three points for the full phonetic structure, and four points if it is spelled completely correctly.

The Developmental Spelling Test (Tangel & Blachman, 1995) used a scale of 0 to 6 and the criteria for each point for each spelling word were described in
detail. This test was more reliable due to its sensitivity to small changes in spelling features that would be expected from a developmental model (VanLoo, 2003).

An alternative approach to complicated spelling assessment is to use a spelling inventory which focuses on assessment of specific features of a word, corresponding to different developmental stages, rather than every letter or feature. The Primary Spelling Inventory (PSI) is a popular method of assessment (Lee, 2012).

**Phonemic Awareness**

Phonological awareness is a broad term used to describe the awareness of sounds within a language, from words and syllables down to phonemes. Phonemes are the short spoken sounds of a language which form syllables and are represented in writing by a single letter or combination of letters. In English, there are about 40 phonemes and 250 ways to spell them (University of Oregon Center on Teaching and Learning, 2002). The sound of a phoneme may vary slightly when used in different words: it is not entirely separable from adjacent phonemes as they affect each other, and it is not possible to say some phonemes in isolation - for example, the sound corresponding to the letter b could be said as *buh* but not *b* alone. PA is knowing that phonemes can be separated and altered to form other words. It requires attention in order to abstract the individual phonemes as normally they are combined at a subconscious level when listening to speech. PA is most important when it comes to reading and writing because sounds are represented with letters (Adams, 1990).

Adams (1990) categorized tasks used to assess PA into five levels: (1) The simplest task, used with very young children, is the saying of nursery rhymes; (2) oddity tasks require the child to identify which word out of 3 or 4 words has a different initial, middle, or final sound - it is considered to be one of the least
demanding tasks because the child does not need to be concerned with many aspects of what a phoneme is or how to answer, merely to make a comparison; (3) blending and syllable-splitting are not simply the opposite of each other - blending involves a child being given a list of sounds which they only need to combine to form a word (/d/ /o/ /g/ = dog), whereas syllable-splitting requires the child to split the initial consonant of a word and say either that phoneme (/d/) or the remainder of the word (/og/); (4) phonemic segmentation goes a step further than syllable-splitting in that it requires the child to split a word into all its constituent phonemes; and (5) phoneme manipulation involves altering a specific phoneme to produce a new word.

Liberman et al. (1974) compared the difficulty of splitting words by syllables and by phonemes, by asking students to tap out the parts using their finger, and concluded that phonemes were considerably more challenging: beyond the ability of nursery school students but achievable by the first grade. Adams (1990) pointed out that type 3 blending tasks are easier if a student is familiar with phoneme sounds as they are easier to remember, whereas type 4 segmentation tasks will be easier if students are familiar with the concept of saying individual phonemes, as may be encountered during phonics instruction; type 5 tasks have good predictive power for reading ability, but their difficulty is beyond a suitable level for grade 1.

Wei (2005) found that phonological awareness in Thai primary school students transferred to English, which was consistent with studies on Chinese and Spanish, which also have different phonological structures to English.

Phonemic awareness is not, in itself, sufficient to be able to spell a word. Students need to be able to represent the sounds they hear with letters, which is the letter-sound correspondence referred to as phonics. Learning the sounds of letters takes longer than learning the names of letters and some letters are easier than others:
the easiest letters have names that contain their sound at the start of the name (e.g., /d/), the next easiest contain the sound at the end (e.g., /f/), and the hardest do not contain the sound (e.g. /y/). Sounds are also more difficult to learn if they represent multiple sounds, as /y/ can in yellow and fly. The difficulty of letter-sounds also reflects the speed with which they can be learnt. Students can access clues to letter-sounds within letter names by splitting the names (Treiman, Tincoff, Rodriguez, Mouzaki, & Francis, 1998); Adams (1990) classified splitting into the third level of PA tasks.

**Phoneme Segmentation Fluency**

The Dynamic Indicators of Basic Early Literacy Skills (DIBELS) (Good & Kaminski, 2002) are a collection of short assessments for monitoring early literacy skills that are widely used in schools in the United States; there are two measures of PA: Initial Sound Fluency for kindergarten, and Phoneme Segmentation Fluency for kindergarten through to first grade. Initial Sound Fluency is a simpler task, matching Adam's (1990) description of a level 3 PA task, whereas Phoneme Segmentation Fluency (PSF) is level 4.

**Memory**

A great deal of research has been done towards modeling the structure of memory and measuring related capacities, but this has also led to a degree of variability in definitions of terms, especially the concept of WM (Milwidsky, 2009). Memory has remained as a topic of interest due to its broad influence on learning, especially the core skills of numeracy and literacy (Bull, Espy, & Wiebe, 2008). Earlier research attributed differences between WM to genetics and not to
environmental factors, but more current research indicates that people can be trained to improve their WM (Alloway, Gathercole, Kirkwood, & Elliott, 2009).

**Models of Memory**

Clues to how memory works have been obtained by studying cases of people whose memory has been impaired in specific ways following sickness, an accident, or surgery. Research using neuroimaging of brain activity during memory tasks has also been done, but the results are complex and open to interpretation (Baddeley, 2007).

Since the 1950s, different models have been proposed regarding WM and its limited capacities. Two ways of describing WM are domain-general or domain-specific. Both types of theory agree that there are two temporary stores which are capable of independently storing visuospatial information (image and location) and phonological information (speech or sound). The theories also agree that as well as simply storing information, it can be processed by a mechanism referred to as the central executive. Here, the theories differ as the domain-specific theories propose that the brain is capable of separately working with visuospatial and phonological information in the same way as it is stored separately, whereas domain-general theories argue that the central executive is not specific to either type of information and is instead a common resource (Milwidsky, 2009).

In 1974, Baddeley and Hitch developed a domain-general model of WM to explain the results of an experiment which involved a processing task being performed under an increasing memory load. They theorized that a controlling system, the central executive, is responsible for attention and processing in complex non-routine tasks, along with two passive (non-processing) information stores which
enable small amounts of recent information to be retrieved. Firstly, the phonological loop is a temporary store of phonological information, assisted by a rehearsal mechanism that repeats the information and prolongs storage which would otherwise last only a matter of seconds; the capacity for phonological storage is VSTM.

Secondly, the visuospatial sketchpad is a system for temporary storage of visual and spatial information which provides visuospatial short-term memory. An important consequence of this model was a better understanding of how information enters long-term memory: simply trying to retain information in short-term memory results in a poor transfer to long-term memory - information must be actively processed in depth (Baddeley, 2007). To resolve some shortcomings with this model, in 2000, Baddeley added a fourth component of WM for more general storage, the episodic buffer, which functions as a bridge between the separate systems, thereby allowing for their integration (Baddeley, 2000).

There is a group of theories based on a different view of short-term memory. These theories propose that, rather than storing information for direct retrieval, it holds a cue to information that is in long-term memory. In a hybrid model between a cue-based memory and a model such as Baddeley's, the process of forgetting is the degradation of the cue, so the stimulus is no longer able to reliably lead to the recall of the information. Other cue-based models offer a more closely unified view of short and long-term memory in which cues are not forgotten, but lost due to interference from new incoming information whose similarities reduce the cue's ability to distinguish a specific piece of information in long-term memory (Nairne, 2002).
Components of Baddeley's Model of Working Memory

The phonological loop appears to be of great significance to language tasks (Baddeley, 1996) and WM is linked with performance in many academic tasks (Alloway & Alloway, 2010).

**Verbal short-term memory: the phonological loop.** The phonological loop appears to be important for children, as well as adults trying to learn a new language, who both need to learn new phonological information. The simplest example of the phonological loop in action is the ability to remember a list of words which can be repeated in about 2 seconds (Baddeley, 1996). The need for rehearsal can also be seen by preventing it via constantly repeating another word. The difficulty of recalling a list is affected by the rate at which words are forgotten and by longer rehearsal times if the length of the words is increased. Recall is maximized if the words are short and said rapidly (Baddeley, 2007).

The phonological loop is not only limited to spoken words, as a reader will subvocalize text. Evidence for this came from demonstrating that, in the same way that a list of words with similar sounds was less accurately recalled, a written list of similarly sounding letters also showed a reduction in performance; on the other hand, words with similar meaning showed only a small decrease. This is the opposite to long-term memory, where similar meaning causes problems, but similar sounds do not. The model does not yet fully explain how the order of items is stored (perhaps based on time or as a sequence) or what happens when the length of the list becomes overwhelming and the rehearsal mechanism fails (Baddeley, 2007).

**Working memory.** Many everyday tasks are performed almost automatically, with little thought required, whereas, when confronted with a challenging new situation, additional attention requires WM. The transition from a
demanding task to one dealt with automatically was demonstrated in 1959 by Mowbray and Rhoades: the time for a reaction task which required a button to be pressed when a corresponding light turned on became slower as more lights were added, but, after enough practice for the task to become automatic, there was no time-penalty when adding more lights (Baddeley, 2007).

Research has supported this domain-general model of WM in which WM resources are shared by different types of tasks, which applies equally to children as young as 4 and adults, with no difference between males and females. The relationship between VSTM and WM does not appear to change as children age, although very young children (4 to 6 years old) make greater use of visuospatial memory when compared with older children (7 to 11 years old) who develop rehearsal strategies that rely on VSTM (Alloway et al., 2006). WM has been found to be stable in students between the ages of 4 and 11 over a 6 year period; it increases with age, but the change is relative to the earlier capacity, so a student with low WM will remain so in comparison to other students. Both VSTM and WM in a child seem to be relatively unaffected by preschool education and their mother's level of education. WM has been found to be significantly related to learning and can be described as a measure of "learning potential" (Alloway & Alloway, 2010, p. 27) in comparison to prior learning which can be reflected in IQ tests.

Examples of WM usage in a school situation would include solving a mathematical equation or processing letters when trying to read an unfamiliar word (Richmond, 2010). Children with a lower WM may become overwhelmed by tasks, incrementally contributing towards a long-term failure to learn, but low WM may go undiagnosed and the problems attributed to an attention deficit disorder. There is some evidence that it may be possible to increase WM through specific training and
subsequently improve academic performance (Alloway & Alloway, 2010; Alloway et al., 2006).

Assessment of Verbal Short-Term Memory and Working Memory

Memory span tasks which establish the maximum length of a list which can be recalled are included in commonly used assessments such as the Wechsler Intelligence Scale for Children - Fourth Edition (WISC-IV), Automated Working Memory Assessment (AWMA), and Working Memory Test Battery for Children (WMTB-C). The tasks can be classified as simple span which involve only storage of information (i.e., VSTM), or complex span which involve processing in addition to storage (i.e., WM) (Dahn, 2008).

A widely accepted assessment of VSTM is the recall of a sequence of digits, referred to as digit span (Gathercole & Pickering, 2000). This is done by the examiner reading aloud a list of randomly ordered, non-repeating digits for immediate recall, which is repeated with lists of increasing length. It is assumed that aurally presenting the numbers avoids the need for subvocalization of written numbers and is therefore the most direct means of accessing VSTM (Baddeley, 2007). Digit span tests may be given using computers, as in the case of the AWMA, but such assessment may be affected by the user's level of experience with computers, especially delays while typing in their response, whereas non-computerized tests merely require the list to be verbally recited (Woods et al., 2011).

Instead of presenting a list of numbers to be recalled in the same order, which is called Digit Span Forward (DSF) or Forward Digit Recall, the list can be repeated in the reverse order, from last to first, which is called Digit Span Backward (DSB) or Backward Digit Recall. Researchers do not always agree on precisely what
is measured by DSB - whether it is VSTM or WM - but there is a growing body of
evidence that, in children, DSB is a measure of WM due to the processing
requirements of reversing the sequence (Alloway et al., 2006; Collifower, 2013;
Gathercole & Pickering, 2000). This appears to be true for children because of limited
use of rehearsal methods, such as grouping digits, and a greater demand on WM from
the task itself, leaving less WM for rehearsal strategies. St Clair-Thompson compared
the correlation of DSF and DSB in children (.33) and adults (.61), which was in
agreement with the use of DSB with children as a measure of WM rather than VSTM
(Gathercole & Pickering, 2000; St Clair-Thompson, 2010). Another way of evaluating
WM is with a letter-number sequencing task where a list of numbers and letters must
be recalled in numerical and then alphabetical order, but this depends on knowledge
of alphabetical order and is rated as having a high degree of linguistic demand in
comparison to the medium degree of digit span tasks (Flanagan & Kaufman, 2004;
Prifitera, Saklofske, & Weiss, 2008).

DSF and DSB can be affected by more than memory capacity,
particularly attentional capacity. The increasing number of digits which must be
recalled requires greater attention to the task (Prifitera et al., 2008). An interesting
finding by Osman and Sullivan (2015) was that WM in children is affected by noise.
In a study involving DSB under quiet conditions compared with noisy conditions that
were not so loud as to cause difficulty in hearing the digits, a greater number of errors
was recorded. The noise appeared to detract attention away from the task, reducing
available WM.
Previous Studies of Spelling Achievement

In a comprehensive analysis of literature regarding early literacy development, the National Institute for Literacy (2008) found that spelling had an average correlation of .40 with phonological awareness (21 studies, 2,522 children) and .31 with VSTM (10 studies, 1,520 children).

A number of studies on memory have included spelling as part of a composite literacy score. With students assessed at age 7 and again at age 8, significant correlations were found in all cases: at age 7 (.52 for WM and .40 for VSTM) and age 8 (.49 for WM and .30 for VSTM) (Gathercole & Pickering, 2000).

In a composite literacy score of children aged 11, where the components of spelling (M = 98.91, SD = 12.52) and reading (M = 98.67, SD = 12.10) had similar values, there was a significant correlation of .36 with WM and .38 with VSTM. These students also had a memory assessment 6 years earlier, at around age 5, and those scores still had similar correlations with their spelling at age 11: WM was .40 and VSTM was .33 (Alloway & Alloway, 2010).

Alloway et al. (2004) found that phonological awareness and VSTM were related but distinct in a study of 4 to 6 year olds. They suggested that spelling would be assisted by segmenting words as a result of phonological awareness, whereas VSTM aids acquisition of phonetic knowledge about letters being represented by sounds and holds this information when combining sounds to spell words; these skills may become less distinct as literacy skills develop with age. VanLoo (2003) had a similar finding that the relationship between spelling and phonological awareness decreased between kindergarten and first grade. However, Lafrance (2007) found similar correlations in grade 1 to grade 3 for both first language and English language learners (.34 to .42, with no trend in the data); additionally, as a predictor of spelling
in sixth grade, (1) first language speakers only had one significant VSTM correlation of .29 in grade 2 but had phonological awareness correlations of .33 to .50, and (2) English language learners had higher correlations of .32 to .36 and .49 to .61 respectively. Keilty and Harrison (2015) had very similar findings: native English speakers used phonological awareness instead of VSTM, whereas second language students used both to deal with the challenge of learning a foreign language, just as Baddeley (1996) described the importance of the phonological loop.

In a study comparing grade 1 South African children, for some of whom their first language was English and for others it was their second language, Milwidsky (2009) found that phonological awareness and VSTM did not correlate with first language students, but did in second language students, which indicated a greater dependency on VSTM. The extent to which WM correlated with phonological awareness tasks was thought to be related to the complexity of the task and therefore the level of demand placed on WM.

Jongejan, Verhoeven, and Siegel (2007) found WM to be a significant predictor of spelling ability in grade 1 to 4 students whose first language was English, but attributed a lack of prediction for second language students to the WM assessment being done in English, which required memory of words in sentences. Phonological awareness, measured by PA tasks and one non-PA task, was the most important predictor for both groups of students.

There is supporting evidence that spelling a word creates a significant WM load even among adults. In a study that involved recalling a list of words under different conditions, when participants wrote down the words while listening - that is, they took notes - then attempted to recall and write them down again, their
performance was significantly lower due to the reduction in available working memory for attention and rehearsal (Tindle & Longstaff, 2015).

Yopp (1995) used data collected from kindergarten students with the Yopp-Singer Test of Phoneme Segmentation to conclude that PA correlated (.44 -.60) with spelling in students as they progressed through primary school, from second grade up to sixth grade.

Teaching PA and knowledge of the correspondence between sounds and letters to kindergarten through to second-grade students had a significant effect on reading and spelling skills which increased with age in comparison to students that did not receive specific training. The exception was students with learning disabilities, who made progress with reading but still had difficulty spelling (Langenthal, 2004). An earlier study suggested that training would only be optimal in improving spelling if it also specifically focused on the correspondence of sounds with letters (Byrne & Fielding-Barnsley, 1995).

Early spelling in kindergarten, assessed using 14 two to four letter words, some of which were decodable and others which were not, showed correlations with two measures of phonological awareness of .46 and .51 (Puranik & AlOtaiba, 2012).

Overall, recent research supports a link between SA and VSTM, WM, and PA, but the extent may vary according to age - particularly between kindergarten and grade 3 - and English language learner status, thus, grade 1 Thai students in an English language program is an interesting combination to study.

**Background of Spelling at Thai Christian School**

Thai Christian School was established in 1968 by the Sapan Luang Christian Church Foundation. It is a school which caters for kindergarten to twelfth
grade students, with approximately 1,000 students altogether. In 1998, an English Program was started, and, beginning in 2010, the Thai Program was phased out. Most grades in the primary level have four classes of approximately 30 students of mixed sex and mixed ability. At the grade one to three levels, English program lessons are by taught by native English speakers and include 6 periods of English, 3 of mathematics, 3 of science, and 1 each of health, social studies, and computer, totaling 15 periods of 50 minutes per week. Regarding the other subjects taught by Thai teachers, these do not include any additional English lessons.

Although spelling is regarded as important at Thai Christian School, no commercial program has been used. Weekly spelling words have been a part of the English program at Thai Christian School since before the author started teaching there in 2008. The word lists and format of the assessment are determined by the relevant teachers, but overall the focus on teaching and assessment gradually shifts from spelling (with the lower grades) to comprehension and usage (with the higher grades).

When the researcher began teaching Grade 1 in 2009, he recognized that the students would need to develop good literacy skills and felt this could be supported through spelling instruction. At the start of the 2015-16 academic year, the researcher made significant changes to the Grade 1 spelling program. The goal was to support students' daily reading and writing, which was centered around the textbook *English World 1* (Bowen & Hocking, 2009), so that they would be less dependent on looking up how to spell words and therefore more able to concentrate on the content of what they were writing and being able to do so faster.

The English curriculum involved reading, writing, listening, and speaking in each unit on topics which included colors, numbers, school, transport, food, nature,
rooms, family, weather, adjectives, verbs (+ing), and adverbs of manner; these took
the form of short dialogues, songs, stories, and writing compositions. Phonics lessons
were taught using English World 1 and Phonics Fun 1 & 2 (Bunton, 2003) which
covered the sounds of consonants, short vowels, and some digraphs (ch, sh, th, wh, ck,
ll, ng); blends were taught informally during day-to-day instruction. Although
students were exposed to the past tense in some dialogues and stories, they were not
explicitly taught about the past tense and did not need to write in the past tense.
Students did use verb+ing words in the final unit of English World 1, but this did not
include spelling rules.

With the Grade 1 spelling program, 10 words were given each week for
22 weeks during the year, totaling 220 spelling words. Each week included 3 phonics
words, of the form consonant-vowel-consonant, taken from their textbooks: Phonics
Fun 1 & 2 (Bunton, 2003) or English World 1 (Bowen & Hocking, 2009); 3 common
words from the top 200 high-frequency words in phases (Department for Education
and Skills (England), 2007); and 4 vocabulary words from an English World 1 unit.
The rationale for including phonics words (e.g., cat) was to ensure students spent time
reviewing letter-sound knowledge; the common words were often not possible to spell
with a simple phonics approach (e.g., two) but are some of the most frequent words in
English text - the words were selected based on their occurrence in English World 1 to
ensure their relevance; and the vocabulary words (e.g. blue) were words central to
students' writing in English World 1 that were usually introduced at the beginning of a
unit. Weekly spelling tests were also used to monitor how well students were able to
spell 5 words randomly selected from the previous 2 weeks. This was also the first
year that spelling pre-tests and post-tests (lists of 20 words) had been used at the start
and end of each quarter of the academic year.
The following paragraphs describe a typical week in which words were introduced, practiced, and tested. Students were introduced to 10 words on Monday with a PowerPoint presentation and they recorded them in a spelling booklet. There were 3 phonics words, 3 common words, and 4 other vocabulary words for which students also drew their own pictures.

Students took home the booklets for the words to be learnt as homework. The words were also written on the side of the whiteboard and each day the teacher erased some letters before reviewing the spelling.

On Thursday, students were shown the words again, played some spelling games as a class, and then they copied the words onto the top of a piece of paper before folding it over and trying to remember the spelling - turning the paper over to check as required - then folding one more time and repeating.

A spelling test was given on Friday, with the words presented in random order within each set. The first 6 words were spoken by the teacher, but the 4 vocabulary words had only the pictures shown on a PowerPoint slide so they must remember the meaning of the word and not just the spelling. Then, 5 random review words from the previous two weeks were read out. A marking scheme recognizing partially-correct words (V. A. Mann et al., 1987) was used, so that 0 - 4 points were available for each word (see the earlier section on spelling assessment), rather than marking correct or incorrect, to track incremental improvements in spelling.

**Summary**

This chapter looked at spelling in the context of effective teaching, theories on how spelling develops in children, and the cognitive architecture of spelling which describes the mental process of spelling. Phonemic awareness was
studied in terms of types of tasks and relative difficulty. Verbal short-term memory
and working memory were examined regarding their roles and limitations. Previous
studies were looked at which included spelling achievement, phonemic awareness,
and memory in students of a similar age. Details on the background of Thai Christian
School and the Grade 1 spelling program were given to establish a context for the
research.

The following chapter gives details of the research undertaken, including
the design, population and sample, research instruments, and data collection
procedures.
CHAPTER III

RESEARCH METHODOLOGY

This chapter presents the research design, population, sample, research instruments, collection of data, data analysis, and summary of the research process, of which the purpose is to investigate levels of phonemic awareness (PA), verbal short-term memory (VSTM), and working memory (WM) in relation to the level of spelling achievement (SA).

Research Design

To investigate the relationship between the three independent variables (PA, VSTM, and WM) with the dependent variable (SA), this quantitative research collected data on Grade 1 students at Thai Christian School. It used four tasks to measure PA, VSTM, WM, and SA respectively: Phoneme Segmentation Fluency (Good & Kaminski, 2002), Digit Span Forward and Digit Span Backward (Wechsler, 2003), and the Primary Spelling Inventory (Bear et al., 2012). After analyzing the results using descriptive statistics, the data was used in a multiple regression analysis to determine if PA, VSTM, and WM could predict SA.

Population

This research relates to Grade 1 students (age 6 to 7) in Thai Christian School, which is a private English program school following the Thai national curriculum. The research was done at the end of the academic year at Thai Christian School which ran from May 2015 to February 2016.
Sample

This research used a population sample from all four Grade 1 classes; two classes with 28 students in each and two with 29 students in each, for a total of 114 students. The students mostly speak Thai as their first language (84% have only Thai parents) but received 15 periods per week of instruction by a native English speaker in a range of subjects.

The four classes were of mixed ability and mixed gender with 58% boys and 42% girls in total. Apart from 1 Korean student and 1 Japanese student, all of the other students were Thai nationals. There were 10 students with a parent from countries where English is not an official language (Japan, South Korea, Vietnam, Norway, and France) and 8 had a parent from either India, Hong Kong, the UK, or the USA. Over half of the students attended kindergarten at Thai Christian School wherein they also received some classes in English from native speakers; others attended a wide range of kindergartens from international schools to kindergartens without native English speakers. Two students joined at the start of the second term.

All 114 students from the four Grade 1 classes were included as although each class had a different teacher responsible for lessons in English, during the year, the teachers followed the same lesson plans, used the same teaching materials, and gave the same assessments. The number of students in each class is shown in Table 1.
Table 1

Number of Students Included in the Study

<table>
<thead>
<tr>
<th>Grade 1 Class</th>
<th>Number of Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 1</td>
<td>28</td>
</tr>
<tr>
<td>Class 2</td>
<td>29</td>
</tr>
<tr>
<td>Class 3</td>
<td>28</td>
</tr>
<tr>
<td>Class 4</td>
<td>29</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>114</strong></td>
</tr>
</tbody>
</table>

Research Instruments

This research uses three standardized instruments which are described in detail below. Phoneme Segmentation Fluency (Good & Kaminski, 2002) is used to assess phonemic awareness (PA). Digit Span includes a forward and a backward task (Wechsler, 2003) that assess verbal short-term memory (VSTM) and working memory (WM) respectively, and the Primary Spelling Inventory (Bear et al., 2012) assesses spelling achievement (SA).

Phoneme Segmentation Fluency for PA

The Phoneme Segmentation Fluency (PSF) task (Good & Kaminski, 2002) was selected to measure the level of Phonemic Awareness (PA) due to the suitable difficulty (within the capability of the age group, yet challenging enough to avoid a ceiling effect) according to the hierarchy of PA tasks described by Adams (1990), as well as availability of data on very large numbers of U.S. students in kindergarten and first grade (Cummings, Otterstedt, Kennedy, Baker, & Kame’enui, 2011). The detailed scoring rubric also gives partial credit for incomplete segmentation, making it suitable for students who may find the task difficult. There
are 20 alternative PSF word lists which can be used for tracking improvement and each list consists of 24 words that contain 3 to 5 phonemes (see Appendix A for the list used).

Reliability of the PSF task was established as .88 and concurrent validity with other reading readiness tasks was .43 to .65 (Good & Kaminski, 1996). Data is available from the DIBELS Data System in the 2009-2010 school year based on more than 600,000 students at each grade level, collected from schools across the USA, including students who may be English language learners - for example, 14% are Hispanic (Cummings et al., 2011).

Scores on the PSF task are interpreted in two ways. (1) There is a single benchmark level of 33 points out of 80 set for kindergarten students in their second term; scoring below 28 may indicate a need for intensive support, or strategic support if in the 28 to 32 point range, in order to reach the benchmark level (Good & Kaminski, 2014). (2) A large table to determine performance in terms of percentile ranks is published in Cummings, Otterstedt, Kennedy, Baker, & Kame’enui (2011) for each term of kindergarten and first grade. Both the benchmark level and percentiles are based on data from students in the USA.

**Digit Span (Forward and Backward) for VSTM and WM**

There are two sections to the Digit Span task (Wechsler, 2003), Digit Span Forward (DSF) and Digit Span Backward (DSB) (Meador, Turner, Lipsey, & Farran, 2013). DSF was used as a measure of Verbal Short-Term Memory (VSTM), whereas DSB was used as a measure of Working Memory (WM) (see Appendix B).

These tasks were selected in preference to other digit span tasks as they could be presented in person by the researcher, rather than using a computer (which
may cause issues with assessment of young children), and this was the only such assessment that the researcher found which allowed for interpretation of VSTM and WM levels separately, rather than combining them as a more general measure of memory and then interpreting that - which is not consistent with research on the topic that these measure two separate constructs for young children.

Reliability of the DSF task was .83 and DSB .80 and, in 2002, it was standardized on 2,200 children (Flanagan & Kaufman, 2004). The validity of DSF and DSB tasks as measures of VSTM and WM respectively has been established (Alloway et al., 2006; Reynolds, 1997; St Clair-Thompson, 2010).

For interpretation of DSF or DSB scores, the raw scores of 0 to 16 points are compared separately with the results of students on whom the tasks were standardized by converting to scaled scores (with values between 1 and 19, where 10 is equivalent to a standard deviation of 0 from the mean). Table 2 shows the criteria for the standardized scores which the researcher used to compare with the results of this research. The values of the raw scores can be used to look up the corresponding scaled scores for 7-year-old students (Wechsler, 2003) along with the interpretation of the scaled scores in terms of the number of standard deviations from the mean (of the group used for standardizing the scale) and corresponding percentile ranks (Weiss, Saklofske, Prifitera, & Holdnack, 2006); suggested descriptors for each range are also shown (Pearson Assessment Support, 2010).
Table 2

Criteria for Interpretation of Digit Span Forward (DSF) and Backward (DSB) Scores as Standardized Scores (Wechsler, 2003; Weiss et al., 2006)

<table>
<thead>
<tr>
<th>Raw Score</th>
<th>Scaled Score</th>
<th>Interpretation of Scaled Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>DSF</td>
<td>DSB</td>
<td>Score</td>
</tr>
<tr>
<td>0</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>-</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>-</td>
<td>-</td>
<td>7</td>
</tr>
<tr>
<td>6</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>-</td>
<td>-</td>
<td>9</td>
</tr>
<tr>
<td>7</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>-</td>
<td>-</td>
<td>11</td>
</tr>
<tr>
<td>8</td>
<td>6</td>
<td>12</td>
</tr>
<tr>
<td>9</td>
<td>-</td>
<td>13</td>
</tr>
<tr>
<td>10</td>
<td>7</td>
<td>14</td>
</tr>
<tr>
<td>11</td>
<td>-</td>
<td>15</td>
</tr>
<tr>
<td>-</td>
<td>8</td>
<td>16</td>
</tr>
<tr>
<td>12</td>
<td>-</td>
<td>17</td>
</tr>
<tr>
<td>13</td>
<td>9-10</td>
<td>18</td>
</tr>
<tr>
<td>14-16</td>
<td>11-16</td>
<td>19</td>
</tr>
</tbody>
</table>

Primary Spelling Inventory for SA

The Primary Spelling Inventory (Bear et al., 2012) was selected to assess spelling achievement based on its use in schools, high reliability with students in grade 1 to 3, inclusion of a good number of words which would allow students to demonstrate what they had learned from their phonics lessons, and being able to interpret student scores in terms of progress in relation to specific spelling features.
The PSI is a developmental spelling assessment used for kindergarten to grade 3 students for placement in ability groups for the Words Their Way word study program. The score was used as a measure of SA (see Appendix C).

The reliability is given as .93 and concurrent validity of .48 to .74 (Bear et al., 2012). Sterbinsky (2007) concluded that it was reliable and valid, plus robust with regards to inclusion of English language learners, special needs, and gifted students.

The PSI score is the number of points for words spelled correctly added to the number of feature points; it is used for tracking student progress. Qualitative interpretation is based on (1) the number of words spelled correctly and (2) the number of feature points missed. First, the number of words spelled correctly gives a score out of 26 which can indicate an overall level of spelling development, as shown in Table 3. Second, the scores out of 7 points for each spelling feature on the rubric are examined: a student who missed 1 point is ready to learn more complex spelling features; a student who missed 2 to 3 points needs to review the feature as this is a stage for further development; missing more than 3 points needs further instruction; and a student who scored 0 needs to study earlier features instead (Bear et al., 2012).

<table>
<thead>
<tr>
<th>Within-Stage Development</th>
<th>Estimated Stage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Emergent Letter Name</td>
</tr>
<tr>
<td>Early</td>
<td>0 8</td>
</tr>
<tr>
<td>Middle</td>
<td>0 2</td>
</tr>
<tr>
<td>Late</td>
<td>6 17</td>
</tr>
</tbody>
</table>
Reliability Statistics

The reliability figures for these instruments, as stated in the literature reviewed earlier, are shown in Table 4. Alongside the reported values are the reliabilities calculated using the data obtained in this research. The reliability for the PSF task was very high (.08 higher than reported); both Digit Span tasks were very similar to the reported values (.06 lower for DSF and .04 lower for DSB); and the PSI task was .11 lower than reported but still reliable.

Table 4

<table>
<thead>
<tr>
<th>Reliability Statistics for the Research Instruments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instrument</td>
</tr>
<tr>
<td>------------------------------------------------</td>
</tr>
<tr>
<td>1. Phoneme Segmentation Fluency (PSF)</td>
</tr>
<tr>
<td>2. Digit Span</td>
</tr>
<tr>
<td>Forward (DSF)</td>
</tr>
<tr>
<td>Backward (DSB)</td>
</tr>
<tr>
<td>3. Primary Spelling Inventory (PSI)</td>
</tr>
</tbody>
</table>

Notes. Split-half reliabilities were calculated using the Spearman-Brown correction (Field, 2009). PSI reliability was calculated using the score for correct/incorrect number of words spelled (Sterbinsky, 2007).

Collection of Data

This section describes the procedures followed for each instrument when collecting the data. The collection was performed in two phases.

In the first phase, for each of the 114 students, the researcher carried out the one-on-one PSF task followed immediately by the DSF and DSB tasks. The PSF task was given first as the score should be less affected by lapses in concentration than the Digit Span tasks and therefore allowed students a chance to settle and focus.
As soon as the PSF task was complete, the DSF and DSB tasks were done according to the order stated in the instrument. During these tasks, the researcher sat opposite the student and used a clipboard when noting the responses (without the student being able to see the sheets). Each student required approximately 6 minutes in total to administer these tasks; the exact time depended on if the example at the start of each task needed to be repeated before they understood and the number of sequences of digits they were able to repeat for DSF and DSB. The researcher spent 1 to 2 hours per day for 9 days collecting data during gaps in the researcher’s teaching duties when students were also able to leave class to participate.

In the second phase, the PSI was given to each of the four classes at the same time by their English teacher (of which the researcher was one the four teachers). This was scheduled for a day on which students were having end-of-year exams and therefore students were already seated in exam positions and a Thai teacher was also in the room to help proctor. An advantage of having each class tested by their regular teacher was that the students would be more familiar with their pronunciation; to reduce any inconsistencies introduced by having different teachers administer the PSI, the researcher gave training and written instructions to the other teachers. The PSI took each teacher approximately 20 minutes to administer.

**Phoneme Segmentation Fluency (PSF)**

This task was given to individual students and involved the researcher saying words from the list for the student to say the individual phonemes. For example, *leaned* should be segmented into 4 phonemes, /l/ /ea/ /n/ /d/. Appendix A gives the list of words used along with the full procedure for administration (including the script) and scoring which the researcher followed. The researcher selected list 15
from the equivalent forms available as the earlier words in the list had either 3 or 4 phonemes each, whereas some lists had words with 5 phonemes early on and these may be difficult words to begin with since the students had not practiced phoneme segmentation prior to the task. List 15 also appeared to have a fair selection of words with regard to sounds that may be specifically problematic for Thai speakers.

After giving the instructions to the student, which included practice with an example word, mop, the researcher timed 1 minute during which the student segmented as many words as possible, with the researcher waiting up to 3 seconds for the student to give the first or next segment of a word. If the student was unable to give any correct segments for the first five words then the task was discontinued. There was no issue with any of the students reaching the end of the list.

The PSF task is scored on the basis of 1 point per correct segment, hence, leaned has a maximum score of 4 points, however, the scoring rubric also recognizes partial segmentation by awarding points to correct segments that are longer than a single phoneme, for example, /l/ /eandi/ would receive 2 points.

The researcher marked the student's responses on the word list by underlining correct segments, putting a slash through incorrect segments, or circling the word if no segments were given correctly. The directions for administration in Appendix A cover how to deal with nine issues that could be encountered when scoring: (1) incomplete segmentation; (2) schwa sounds; (3) additions; (4) articulation/dialect; (5) sound elongation; (6) no segmentation; (7) overlapping segments; (8) omissions; and (9) mispronunciation.
Digit Span Forward and Backward (DSF and DSB)

These two tasks both involved the researcher saying sequences of numbers of increasing length for the student to repeat. Appendix B gives the task scripts and record sheets.

The first task was DSF. The researcher gave the instructions to the student, and practiced with the student repeating first one digit and then a sequence of 2 digits in the order given. The researcher spoke the digits with 1 second between each one, with the final digit signaled by a slightly lower tone of voice.

The rate at which numbers were said was a crucial aspect of the task due to the limited time information is held in VSTM without rehearsal. The researcher practiced in advance, but also made use of a metronome smartphone application (Jak, 2014) set to vibrate every second to ensure the researcher could maintain the correct pace without causing a distraction for the student.

If the student was able to repeat either one or both sequences of digits at a certain length, then the researcher progressed to the next pair of sequences which were one digit longer and continued in this manner until the student was unable to correctly repeat either sequence at that length. One point was scored for each correct sequence, with a maximum score of 16 points.

The procedure for the DSB task was different in that the numbers must be repeated in reverse order, from last to first. After giving instructions, it was practiced twice with sequences of 2 digits (Flanagan & Kaufman, 2004; Meador et al., 2013).

Primary Spelling Inventory (PSI)

The PSI consists of 26 words which were read aloud by the teachers for their class of students to write down the spelling. Appendix C gives detailed
directions, the task script provided to each teacher, the sheet for students to write their spellings, and the guide for scoring.

The PSI provides an optional sentence which can be read by the teacher to clarify the meaning of each word to be spelled, but it warns that they may have a negative effect by making the test take longer. The researcher chose not to use them as there were no ambiguous words, the sentences could confuse non-native English speakers, and the students' regular weekly spelling tests did not include examples.

The words are ordered in terms of increasing developmental stages from letter name–alphabetic through to within word pattern. Since the words are ordered, the directions for the PSI suggest it may not be necessary to read all the words in the list if students are unable to spell beyond a certain point, but since the researcher was unsure about the range of spelling ability, all words were included. In accordance with the directions, students did not study the words in advance.

Prior to giving the test, the researcher briefed the other three teachers on the procedure. Teachers followed the Teacher's Administration Notes shown in Appendix C, which included the script to introduce the test and the words themselves.

The PSI was given on one of the days of students' final exams and so they were already seated in exam conditions and a Thai teacher was also in each room to assist with proctoring. No standard sheet for students answers is provided with the PSI since it suggests students may write their own numbered list or the teacher may provide one: hence, students were given an answer sheet created by the researcher with spaces to write their answer, formatted in a style with which students were familiar from spelling pre/post-tests done earlier in the year.

All scoring was done by the researcher using the rubric which awards points for specific spelling features in each word and one point for correctly spelling
the whole word. The researcher was also careful to follow the guidance on common confusions in scoring (Bear et al., 2012) which advised not to penalize students for the handwriting mistake of writing letters in a reversed manner, such as $b$ and $d$, and to give students credit for representing spelling features correctly even if letters are not in the correct order or if they added additional letters - although in the latter two cases the point for correctly spelling the word would not be given.

**Summary**

The timeline for the collection of data is outlined in Table 5.

**Table 5**

*Timeline for Collection of Data During 2016 at Thai Christian School*

<table>
<thead>
<tr>
<th>Date</th>
<th>Data Collection Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>February 5th</td>
<td>Permission from the director of Thai Christian School.</td>
</tr>
<tr>
<td>February 8th - 17th</td>
<td>Collect data: (1) Phoneme Segmentation Fluency and (2) Digit Span (forward, then backward) - administered to individual students by the researcher.</td>
</tr>
<tr>
<td>February 17th</td>
<td>Collect data: (3) Primary Spelling Inventory - administered to the whole class by each class' homeroom English teacher (including the researcher).</td>
</tr>
</tbody>
</table>

**Data Analysis**

The quantitative data analysis techniques used for each research objective are listed below:

1. To determine the PA of Grade 1 students at Thai Christian School, the mean and standard deviation are calculated.
2. To determine the VSTM of Grade 1 students at Thai Christian School, the mean and standard deviation are calculated.

3. To determine the WM of Grade 1 students at Thai Christian School, the mean and standard deviation are calculated.

4. To determine the SA of Grade 1 students at Thai Christian School, the mean and standard deviation are calculated.

5. To determine the significance and direction of the predictive relationships between phonemic awareness, verbal short-term memory, and working memory with spelling achievement of Grade 1 students at Thai Christian School, a multiple regression analysis is performed.

**Multiple Regression**

There are a range of types of regression for researchers to choose from, including multiple regression, nonlinear regression for data that does not follow a linear relationship, and the multivariate general linear model for more than one dependent variable. *Multiple regression* was selected for this research as it is suitable for investigating multiple independent variables with a linear relationship to a single dependent variable. Multiple regression is also referred to as *ordinary least squares regression* since the regression line is fitted to the data by minimizing the sum of the squared distance of each data point from the line (Garson, 2014; Ho, 2006).

The *variance* is the sum of squared errors divided by the sample size minus 1; it relates to the spread of values whilst taking into account the number of data points (Field, 2009). In multiple regression, a *predictive relationship* refers to the ability of a group of independent variables to explain a part of the observed variance in the dependent variable. The correlations between the independent variables and the
dependent variable determine if they are able to significantly contribute to the prediction and to what extent. Hence, high correlations can produce a model (an equation) which can accurately predict a value from a set of variables (Garson, 2014).

**Requirements and assumptions.** Multiple regression requires a sample size that is large enough when considering the number of independent variables involved. The sample should be more than 20 times greater than the number of independent variables (Ho, 2006); for a regression involving 3 independent variables, there should be a minimum sample size of 60.

Calculations of statistical significance assume data with a *normal distribution*. A histogram should show central tendency where most results fall near the middle of the range, with fewer and fewer in the tails. The *standard deviation* indicates the spread of the results as it is the square root of the variance. In a normal distribution, the *mode* (most common value), *median* (the middle score when sorted by value), and *mean* (average score) are all equal. However, the distribution may have a positive or negative *skew* where one of the tails is longer or thicker; the mode, median, and mean values will differ. Skew can be dealt with by applying a transformation: a negative skew first needs to be reflected by subtracting each value from the maximum value and adding 1 (since scores between 0 to 1 will be affected differently to those greater than 1), then either calculating the square-root (a weak transformation), log, or reciprocal (a strong transformation); if the values were reflected earlier, they can be reflected again to restore the correct order. Skew is a worse problem when an independent variable and the dependent variable are skewed in opposite directions. Another issue is *kurtosis*, which relates to the height of the peak (Field, 2009; Garson, 2014; Osborne, 2002). Whether or not skewness and kurtosis are within acceptable limits depends on the sample size; the *z* score (from a
distribution with a mean of zero and standard deviation of 1) can be calculated by dividing each value by its standard error (SE), where, for a sample size between 50 and 300, an absolute value above 3.29 would mean the distribution is non-normal at the .05 significance level (Kim, 2013).

A linear relationship between the independent variables and the dependent variable is an assumption necessary for correlation. Performing Pearson product-moment correlations can indicate any problems with linearity or multicollinearity (described below) before proceeding further. If a relationship is not linear, it needs a mathematical transformation applied to make it so (Ho, 2006). Linearity can be assessed by inspecting residual plots which show the standardized residual of the dependent variable against an independent variable. A residual is the difference between the predicted and observed values and it is standardized by dividing by its standard deviation (the square root of the variance), which makes the mean zero and the standard deviation equal to 1. A fitted line (such as a loess smoothing line, which applies a weighted least squares method) should not appear to be curved if the relationship is linear (Garson, 2014).

Multicollinearity is a problem which occurs when one or more independent variables are correlated with each other. If such a pair of variables are included in the regression, they undermine each other's individual predictive power as they provide similar contributions. The occurrence of multicollinearity can be identified by checking if independent variables have tolerance values less than 0.1, which means there is very little unique contribution (Ho, 2006).

Homoscedasticity describes the desired situation of the dependent variable having an equal variance at different values of an independent variable. That is to say, the distance from the mean remains similar across the range as the effect size of the
independent variables does not vary. This assumption can be checked with a residual plot showing standardized residual values against standardized predicted values; the data points should be spread equally above and below the x-axis along its length. A further test for homoscedasticity is the Breusch-Pagan test which, if statistically significant, is evidence of a linear trend in variance rather than homoscedasticity. A lack of homoscedasticity might be corrected with a transformation (square root, log, or reciprocal) of the dependent, otherwise alternative forms of regression might be used, such as weighted least squares or quantile regression (Garson, 2014).

Two further assumptions are made regarding errors. The error in each case should be independent of the next case if measurements must be made in a fixed sequence of time, which is not applicable to this research. The errors should also be normally distributed since a model that fits well should result in little error for most predictions, with few large errors; a histogram of standardized residuals can be inspected for the presence of a normal curve (Garson, 2014; Ho, 2006).

A final consideration is the effect of outliers. These are unusual cases where the predicted value is extremely different from the observed value. There are several ways of assessing if outliers are present and the seriousness of their effect. Field (2009) described the following set of tests to check for outliers: (1) Cook's distance relates to the extent a particular case affects the whole model and should not be greater than 1; (2) the leverage value is between 0 and 1 according to the amount of influence on the predicted value of the dependent variable - an outlier is considered to have a value 2 or 3 times \((k + 1)/n\) (where \(k\) is the number of independent variables and \(n\) is the sample size) but its Cook's distance value should also be checked to see the overall effect on the model; (3) the acceptable Mahalanobis distance from the mean values of the independent variables increases with sample size and should be
less than 15 for a sample of 100 when there are three independent variables; (4)

*standardized DFBeta* values show the size of the effect on the individual coefficients
in the regression equation if a case is excluded - outliers have absolute values greater
than 1; and (5) the *covariance ratio* (CVR) is the effect of a sample on the variance of
the regression coefficients - a value departing from 1, outside the range $1 - 3(k+1)/n$ to
$1 + 3(k+1)/n$, indicates it is influential. Field advised that outliers should not be deleted
provided that their influence is not too great (Cook's distance $< 1$), but the researcher
should try to explain why the model was not able to account for outlying values.

**Regression techniques.** A decision must be made as to which technique
is to be used when performing a regression analysis. The selection affects the order in
which independent variables are included - or excluded - and the significance of a
variable if it correlates with another. The main techniques are: (1) *standard* - all
variables are entered and evaluated, (2) *hierarchical* - the order of entry is selected
based on reasoning or theory, and (3) *statistical* - inclusion is a process determined
automatically by correlation and other statistical criteria, but it is sensitive to
multicollinearity. When the order of variables is unclear, a statistical approach may be
taken and a further choice must be made: variables may be entered with the *forward*
method (selecting in order of decreasing correlation), the *backward* method
(eliminating variables which do not contribute to the model), and the *stepwise* method
(which combines forward and backward methods to ensure variables remain
significant after others are entered and therefore may be a preferred method) (Garson,
2014; Ho, 2006). Based on these reasons, this research made use of a statistical
technique using a stepwise method.
Summary of the Research Process

The research objectives, source of data or sample, research instruments, and data analysis are shown in Table 6.

Table 6

<table>
<thead>
<tr>
<th>Research Objective</th>
<th>Source of Data or Sample</th>
<th>Research Instrument</th>
<th>Data Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) To determine the level of phonemic awareness of Grade 1 students at Thai Christian School.</td>
<td>114 Grade 1 students at Thai Christian School, Term 2, 2015-16</td>
<td>Phoneme Segmentation Fluency</td>
<td>M SD</td>
</tr>
<tr>
<td>2) To determine the level of verbal short-term memory of Grade 1 students at Thai Christian School.</td>
<td></td>
<td>Digit Span Forward</td>
<td>M SD</td>
</tr>
<tr>
<td>3) To determine the level of working memory of Grade 1 students at Thai Christian School.</td>
<td></td>
<td>Digit Span Backward</td>
<td>M SD</td>
</tr>
<tr>
<td>4) To determine the level of spelling achievement of Grade 1 students at Thai Christian School.</td>
<td></td>
<td>Primary Spelling Inventory</td>
<td>M SD</td>
</tr>
<tr>
<td>5) To determine if there is a significant positive predictive relationship between phonemic awareness, verbal short-term memory, and working memory with spelling achievement of Grade 1 students at Thai Christian School.</td>
<td>Data from objectives 1-4</td>
<td>-</td>
<td>Multiple regression</td>
</tr>
</tbody>
</table>
CHAPTER IV

RESEARCH FINDINGS

This chapter presents the research findings from the data collected with the Grade 1 students ($N = 114$) at Thai Christian School for the five research objectives. The first four findings relate to establishing the levels of students' phonemic awareness, verbal short-term memory, working memory, and spelling achievement. The fifth finding is about the predictive relationship between the variables with spelling achievement.

Research Objective One

The first research objective was to determine the level of phonemic awareness (PA) of Grade 1 students at Thai Christian School.

The researcher administered a 1-minute timed assessment using a Phoneme Segmentation Fluency (PSF) task (Good & Kaminski, 2002) to individual students. The score was the number of phonemes correctly segmented.

Scores ranged from 0 to 56 points out of 80 ($M = 24.90$, $SD = 12.47$). The mean score was below the benchmark score of 33 points described by Good and Kaminski (2014), and below the level where U.S. kindergarten students in their second term scoring below 28 may need intensive support to reach the benchmark.

The percentile rank of the mean score of students in this study was only 3, which is in the well-below average range (3rd to 8th percentile) for U.S. students also at the end of grade 1; the highest scoring student would be ranked as average (62nd percentile) (Cummings et al., 2011).
Research Objective Two

The second research objective was to determine the level of verbal short-term memory (VSTM) of Grade 1 students at Thai Christian School.

Immediately after administering the PSF task, the Digit Span Forward (DSF) task (Wechsler, 2003) was carried out, where the student would repeat the list of numbers said by the researcher until they failed to correctly repeat both lists for the same number of digits. The score was the number of lists correctly repeated.

Scores ranged from 3 to 13 points out of 16. Referring to Table 2, the mean DSF score \(M = 7.72, SD = 1.94\) was equivalent to a scaled score between 10 and 12 which corresponds to between 0 and 0.67 SDs above the standardized mean and a percentile rank of 50 to 75, which is described as average.

The highest score of 13 points was equivalent to a scaled score of 18: 2.67 SDs above the standardized mean and a percentile rank of 99.6, which is described as superior.

Research Objective Three

The third research objective was to determine the level of working memory (WM) of Grade 1 students at Thai Christian School.

Following on from the DSF task, the Digit Span Backward (DSB) task (Wechsler, 2003) was carried out. This task was the same as the DSF task except that the student had to repeat the digits in reverse order. The score was the number of lists correctly repeated.

Scores ranged from 0 to 8 points out of 16. The mean DSB score \(M = 4.99, SD = 1.57\) was equivalent to a scaled score of 10 (see Table 2), which
corresponds to 0 SDs from the standardized mean and a percentile rank of 50, which is described as average.

The highest score of 8 points was equivalent to a scaled score of 16:
2 SDs above the standardized mean and a percentile rank of 98, which is described as superior.

**Research Objective Four**

The fourth research objective was to determine the level of spelling achievement (SA) of Grade 1 students at Thai Christian School.

The Primary Spelling Inventory (PSI) (Bear et al., 2012) was administered to each class as a group. Scoring followed the rubric which awarded feature points and points for correctly spelling words.

Referring to the results shown in Table 7 and the stages of spelling development in Figure 3, the mean score for the number of words spelled correctly would indicate that the students are in the middle of the letter name-alphabetic spelling stage, which spans from kindergarten to the middle of second grade. The highest scoring student is in the middle of the next stage: within word pattern spelling, which spans from first grade to the middle of fourth grade.

The mean feature point scores in Table 7 show that on average students are near to only missing 1 point (1.32 points missed) on the initial consonants feature; they missed between 2 and 3 points (2.10 and 2.36 points missed) on the final consonants and short vowels features respectively; missed more than 3 points (4.57 and 4.75 points missed) on digraphs and blends; and scores were close to 0 points (0.46, 0.55, and 0.42 points) for common long vowels, other vowels, and inflected endings.
The scores categorized students as near to mastering initial consonants; needing further practice with final consonants and short vowels; needing further instruction regarding digraphs and blends once they had mastered earlier stages; and common long vowels, other vowels, and inflected endings were well-beyond their stage of development. The spelling feature scores put students at an early to middle letter name-alphabetic stage of development.

The highest scores on each spelling feature showed that some students had mastered initial and final consonants, short vowels, digraphs and blends; they were developing knowledge of common long vowels; however, they were still in need of further instruction on other vowels and inflected endings. Thus, the highest achieving students were developing in the early to middle part of the within word pattern stage.

A more detailed view of the results is presented in Table 8, which shows numbers of students scoring each number of feature points with the level of spelling development being assessed increasing from left to right.
Table 7

Primary Spelling Inventory (PSI) Scores Overall and for Each Spelling Feature

<table>
<thead>
<tr>
<th>PSI Score</th>
<th>$M$</th>
<th>$SD$</th>
<th>Min.</th>
<th>Max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>25.11</td>
<td>12.20</td>
<td>0</td>
<td>58</td>
</tr>
<tr>
<td>Correct Words</td>
<td>3.77</td>
<td>2.96</td>
<td>0</td>
<td>15</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Feature</th>
<th>Spelling Stage Range</th>
<th>$M$</th>
<th>$SD$</th>
<th>Min.</th>
<th>Max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Consonants:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>initial</td>
<td>Emergent (L)</td>
<td>5.68</td>
<td>1.73</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>2. Consonants:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>final</td>
<td>Emergent (L) -</td>
<td>4.90</td>
<td>1.98</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Letter name-alphabetic (E)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Short vowels</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Letter name-alphabetic (E) -</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Letter name-alphabetic (M)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Digraphs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Letter name-alphabetic (M) -</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Letter name-alphabetic (L)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Blends</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Within word pattern (E)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Common</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>long vowels</td>
<td>Within word pattern (E) -</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Within word pattern (M)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Other</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>vowels</td>
<td>Within word pattern (M) -</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Within word pattern (L)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Inflected endings</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Within word pattern (L) -</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Syllables and affixes (E)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes. PSI scores were out of 82 points in total, 26 points for words spelled correctly, and 7 points for each feature. Min. = minimum score, Max. = maximum score. (E) = early stage, (M) = middle stage, (L) = late stage.
Table 8

Number of Students Who Scored Each Number of Feature Points on the Primary Spelling Inventory

<table>
<thead>
<tr>
<th>Feature Points Scored</th>
<th>Consonants: Initial</th>
<th>Consonants: Final</th>
<th>Short Vowels</th>
<th>Digraphs</th>
<th>Blends</th>
<th>Common Long Vowels</th>
<th>Other Vowels</th>
<th>Inflected Endings</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>48</td>
<td>25</td>
<td>19</td>
<td>2</td>
<td>9</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>31</td>
<td>27</td>
<td>21</td>
<td>6</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>16</td>
<td>30</td>
<td>30</td>
<td>12</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>6</td>
<td>11</td>
<td>14</td>
<td>13</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>5</td>
<td>3</td>
<td>13</td>
<td>17</td>
<td>4</td>
<td>5</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>7</td>
<td>10</td>
<td>23</td>
<td>4</td>
<td>9</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>3</td>
<td>5</td>
<td>5</td>
<td>18</td>
<td>14</td>
<td>22</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>3</td>
<td>6</td>
<td>2</td>
<td>23</td>
<td>88</td>
<td>76</td>
<td>78</td>
<td></td>
</tr>
</tbody>
</table>

Feature Points Missed

<table>
<thead>
<tr>
<th></th>
<th>0-1: Ready to move on</th>
<th>2-3: Needs to review</th>
<th>4-6: Needs further instruction</th>
<th>7: Study earlier features</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-1: Ready to move on</td>
<td>79</td>
<td>52</td>
<td>40</td>
<td>8</td>
</tr>
<tr>
<td>2-3: Needs to review</td>
<td>22</td>
<td>41</td>
<td>44</td>
<td>25</td>
</tr>
<tr>
<td>4-6: Needs further instruction</td>
<td>10</td>
<td>15</td>
<td>28</td>
<td>58</td>
</tr>
<tr>
<td>7: Study earlier features</td>
<td>3</td>
<td>6</td>
<td>23</td>
<td>34</td>
</tr>
</tbody>
</table>

Note. Numbers in bold are the greatest number of students within each feature.

Research Objective Five

The fifth research objective was to determine if there is a significant positive predictive relationship between phonemic awareness (PA), verbal short-term memory (VSTM), and working memory (WM) with spelling achievement (SA) of Grade 1 students at Thai Christian School.
The hypothesis was that there are positive predictive relationships between PA, VSTM, and WM with SA of Grade 1 students at Thai Christian School such that the higher their PA, VSTM, and WM, the higher will be their SA.

A multiple regression was performed to see if PSF, DSF, and DSB scores (as measures of PA, VSTM, and WM respectively) predicted the score on the PSI (as a measure of SA). The steps followed in performing the analysis were detailed in the Data Analysis section of Chapter III.

**Requirements and Assumptions for Multiple Regression**

The following sections provide the results of checks on the requirements and assumptions necessary for multiple regression, then the results of the regression itself are presented in the section after.

**Correlations.** Before proceeding with the regression, a Pearson product-moment correlation was performed to verify that there did appear to be significant relationships with PSI scores and that there were no indications of high correlations between the independent variables; these results are shown in Table 9.

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Phoneme Segmentation Fluency (PSF)</td>
<td>---</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Digit Span Forward (DSF)</td>
<td>.22*</td>
<td>---</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Digit Span Backward (DSB)</td>
<td>.17</td>
<td>.14</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td>4. Primary Spelling Inventory (PSI)</td>
<td>.57**</td>
<td>.36**</td>
<td>.30**</td>
<td>---</td>
</tr>
</tbody>
</table>

**Notes:** *N = 114. *p < .05; **p < .01
Normal Distributions. Histograms of the variables should show a central tendency, with tails and peaks that do not indicate problems with skew or kurtosis. Acceptable skew and kurtosis limits can be calculated as z scores; absolute values above 3.29 indicate the distribution is non-normal at the .05 significance level.

Table 10 shows descriptive data for the distribution of each variable; histograms for each distribution are included in Appendix D. The distributions for PSF, DSF, and PSI were found to be normal, whereas the DSB distribution was found to be moderately non-normal regarding both skewness ($z = -5.17$) and kurtosis ($z = 5.99$); the skew was also in the opposite direction to the PSI skew. A square-root transformation was chosen to improve the normality of the DSB data as it was the weakest of the transformations: the data was reflected by subtracting each value from the greatest value, 8, adding 1, taking the square root, then reflecting back to the original order by multiplying by negative 1. The transformed square root of DSB (Sqrt.DSB) had acceptable skewness ($z = 1.30$) and kurtosis ($z = 2.86$).

Table 10

| Variable   | $M$  | $SD$  | Skewness |  | Kurtosis |  |
|------------|------|-------|----------|  |----------|  |
| PSF        | 24.90| 12.47 | -0.20    | 0.23 | -0.87    | -0.49 | 0.45 | -1.09 |
| DSF        | 7.72 | 1.94  | 0.29     | 0.23 | 1.27     | 0.11  | 0.45 | 0.24  |
| DSB        | 4.99 | 1.57  | -1.17    | 0.23 | -5.17    | 2.69  | 0.45 | 5.99  |
| PSI        | 25.11| 12.20 | 0.29     | 0.23 | 1.28     | -0.06 | 0.45 | -0.14 |
| Sqrt.DSB   | -1.97| 0.38  | -0.29    | 0.23 | -1.30    | 1.28  | 0.45 | 2.86  |

Notes. PSF = Phoneme Segmentation Fluency; DSF = Digit Span Forward; DSB = Digit Span Backward; PSI = Primary Spelling Inventory; Sqrt.DSB = DSB corrected for normality with a square-root transformation.
Multiple Regression Method. A statistical approach to the multiple regression was taken as there was no clear order for variables to be entered; a stepwise method was used to ensure entered variables remained significant. PSF, DSF, and Sqrt.DSB (the transformed DSB data) were entered as independent variables with PSI as the dependent variable. The statistical data generated from the regression was checked to ensure other requirements and assumptions had been met.

Homoscedasticity. The multiple regression produced a model which included all three independent variables as predictors with a significance of .05 or better. However, although there were no issues with linearity or multicollinearity, a plot of standardized residuals against standardized predicted values showed a fan-shaped spread, increasing from left to right, typical of a lack of homoscedasticity (see Figure 5).

Figure 5. Standardized residual plot showing a lack of homoscedasticity. The residual plot showed a lack of homoscedasticity (a cone widening from left to right) in the regression analysis of PSF, DSF, and Sqrt.DSB with PSI.
Running a Breusch-Pagan test ($X^2 = 3.48, p = .06$) confirmed the lack of homoscedasticity with a significance on the borderline of the .05 level. Since the lack of homoscedasticity was moderate, following Garson’s (2014) suggestion, a square root transformation of the dependent (referred to as Sqrt.PSI) was carried out (after adding 1 due to the presence of values of 0, as was discussed when correcting for skew earlier).

**Multiple Regression Corrected for Homoscedasticity**

The regression was repeated with PSF, DSF, and Sqrt.DSB (the transformed DSB data) and Sqrt.PSI as the dependent variable to correct for homoscedasticity. Checks were repeated to ensure all requirements and assumptions were still met and outliers were examined in detail.

**Normal Distribution of Sqrt.PSI.** The distribution of Sqrt.PSI was checked to ensure it was still normal; it was found to be within acceptable limits ($z < 3.29$) (see Table 11).

| Table 11 |
|-----------------|-----------------|-----------------|-----------------|
| **Comparison of Normal Distributions of PSI and Sqrt.PSI** |

<table>
<thead>
<tr>
<th>Variable</th>
<th>$M$</th>
<th>$SD$</th>
<th>Skewness</th>
<th>Kurtosis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Statistic</td>
<td>SE</td>
</tr>
<tr>
<td>PSI</td>
<td>25.11</td>
<td>12.20</td>
<td>0.29</td>
<td>0.23</td>
</tr>
<tr>
<td>Sqrt.PSI</td>
<td>4.95</td>
<td>1.29</td>
<td>-0.50</td>
<td>0.23</td>
</tr>
</tbody>
</table>

**Notes.** PSI = Primary Spelling Inventory; Sqrt.PSI = Primary Spelling Inventory (PSI) corrected for borderline homoscedasticity with a square-root transformation.
**Linear Relationships.** Fitted lines on plots of the standardized residual of the dependent (Sqrt.PSI) against each independent variable did not appear to be curved (see Appendix E).

**Multicollinearity.** There were no issues with multicollinearity as the tolerance values of PSF (.94), DSF (.94), and Sqrt.DSB (.97) were much greater than the minimum of .10.

**Homoscedasticity.** After transforming the PSI values to correct for an earlier lack of homoscedasticity, Sqrt.PSI no longer shows residuals that fan out (see Figure 6). A second Breusch-Pagan test ($\chi^2 = 0.43, p = .51$) confirmed improvement.

![Figure 6](image.png)

*Figure 6.* Standardized residual plot showing improved homoscedasticity.

Homoscedasticity improved after applying a square-root transformation to PSI scores in the regression analysis of PSF, DSF, and Sqrt.DSB with Sqrt.PSI.
**Normally Distributed Errors.** Standardized residuals were checked and found to be normally distributed with acceptable skewness ($z = -1.14$) and kurtosis (-0.20) (see Appendix F).

**Outliers.** No outliers were excluded. Five checks for outliers were performed: (1) Cook’s distance was less than 1.00 (Maximum = 0.09); (2) no leverage values were greater than the limit of $3(k + 1)/n$, calculated to be 0.11 (Maximum = 0.09); (3) Mahalanobis distances were all less than 15 (Maximum = 10.6); (4) standardized DFBeta absolute values were less than 1.00 for PSF (Maximum = 0.39), DSF (Maximum = 0.56), and Sqrt.DSB (Maximum = 0.28); and (5) there were 15 values of covariance ratio (CVR) found to exceed the range $1 \pm 3(k+1)/n$ (from 0.89 to 1.11) with values in the range of 0.84 to 1.15. Plots of CVR outliers and CVR$^{-}$ against other outlier measures are shown in Appendix G and discussed in Chapter V.

**Regression Results**

Table 12 shows the results of the multiple regression analysis of PSF, DSF, and Sqrt.DSB with Sqrt.PSI; results are also shown for the uncorrected PSI model which had a borderline issue with homoscedasticity. Figure 7 shows predicted spelling achievement against actual achievement; the gradient of the fitted line is equal to $R^2$. 
Table 12

Multiple Regression Analyses for Variables Predicting Spelling Achievement

<table>
<thead>
<tr>
<th>Variable</th>
<th>Sqrts.PSI model</th>
<th>Uncorrected PSI model</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B</td>
<td>SE B</td>
</tr>
<tr>
<td>PSF</td>
<td>0.05</td>
<td>0.01</td>
</tr>
<tr>
<td>DSF</td>
<td>0.14</td>
<td>0.05</td>
</tr>
<tr>
<td>Sqrt.DSB</td>
<td>0.66</td>
<td>0.25</td>
</tr>
<tr>
<td>(Constant)</td>
<td>3.83</td>
<td>0.67</td>
</tr>
</tbody>
</table>

$R^2$       | .44  |        | .41     |
$F$         | 28.52*** |       | 25.77***|

Notes. Sqrts.PSI = Primary Spelling Inventory (PSI) corrected for borderline homoscedasticity with a square-root transformation.

$N = 114$. *$p < .05$. **$p < .01$. ***$p < .001$.

Figure 7. Predicted spelling achievement against actual achievement (Sqrts.PSI).
Table 13 gives correlations for the interpretation of each variable's contribution: the *zero-order correlation* is Pearson's $r$ where all variables are allowed to vary and is therefore not a unique contribution; the *partial correlation* relates to the unique variance when all other variables are controlled for in the independent and dependent variables; the *part correlation* (or semi-partial correlation) relates to the total variance as it includes both the unique and joint contribution when other variables are controlled for in the independent variable alone. Differences in the various correlation values can indicate the relationship with the other independent variables (Field, 2009; Garson, 2014).

Table 13

*Multiple Regression Correlations With Sqrt.PSI*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Zero-order</th>
<th>Partial</th>
<th>Part</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSF</td>
<td>.59</td>
<td>.56</td>
<td>.50</td>
</tr>
<tr>
<td>DSF</td>
<td>.35</td>
<td>.26</td>
<td>.20</td>
</tr>
<tr>
<td>Sqrt.DSB</td>
<td>.30</td>
<td>.25</td>
<td>.19</td>
</tr>
</tbody>
</table>

*Notes.* Sqrt.PSI = Primary Spelling Inventory (PSI) corrected for borderline homoscedasticity with a square-root transformation; PSF = Phoneme Segmentation Fluency; DSF = Digit Span Forward; Sqrt.DSB = DSB corrected for normality with a square-root transformation.

**Summary**

DSB was corrected for a lack of normal distribution (Sqrt.DSB) and PSI was adjusted for a borderline issue with homoscedasticity (Sqrt.PSI). This model passed checks of assumptions and requirements, with some values being indicated as CVR outliers, but not by other measures of outliers. Positive predictive relationships between PA, VSTM, and WM with SA were found, therefore the hypothesis is accepted at the .05 significance level.
**Further Finding: Trends in Spelling Achievement**

Following the regression, the researcher was interested in trying to visualize how students' actual SA had related to combinations of high and low levels of PSF, VSTM, and WM. This was problematic as variance was quite high and the correlations for VSTM and WM were quite low, thereby tending to mask obvious trends. The researcher reduced this problem of interpreting combinations of levels by grouping data under simple descriptions using ranges of values that created groups of roughly equal sizes: VSTM and WM performance with z scores above 0 were designated as high, and below 0 as low; PSF performance was better correlated with PSI, so the researcher split this into 3 groups of cases being low (z < -0.5), medium (-0.5 < z < 0.5) and high (z > 0.5). The results are shown in Figure 8.

![Boxplots showing varying PSI scores](image)

Figure 8. Spelling achievement grouped by performance on other variables.

The boxplots show Primary Spelling Inventory (PSI) scores for low, medium and high phoneme segmentation fluency (PSFGroup) when also grouped as having (1) both low verbal short-term memory (VSTM) and working memory (WM), (2) low VSTM or low WM, and (3) both high VSTM and WM.
CHAPTER V

CONCLUSIONS, DISCUSSION, AND RECOMMENDATIONS

This chapter presents a summary of the study and its findings, the conclusions from the findings and discussion in relation to the research objectives and hypothesis, and makes recommendations for how teachers can improve spelling achievement, for administrators to support spelling development, and possible improvements for future research.

Summary of the Study

This research studied levels of phonemic awareness (PA), verbal short-term memory (VSTM), working memory (WM), and spelling achievement (SA) and investigated the predictive relationship between PA, VSTM, and WM with SA of Grade 1 students at Thai Christian School.

The research instruments used were: (1) a Phoneme Segmentation Fluency (PSF) task (Good & Kaminski, 2002) for the level of PA, (2) a Digit Span Forward (DSF) task and Digit Span Backward (DSB) task (Wechsler, 2003) for VSTM and WM respectively, and (3) Primary Spelling Inventory (PSI) (Bear et al., 2012) for SA. To investigate the predictive relationship with SA, the researcher carried out a multiple regression.

The research objectives were:

1. To determine the level of PA of Grade 1 students at Thai Christian School.
2. To determine the level of VSTM of Grade 1 students at Thai Christian School.
3. To determine the level of WM of Grade 1 students at Thai Christian School.
4. To determine the level of SA of Grade 1 students at Thai Christian School.

5. To determine if there is a significant positive predictive relationship between PA, VSTM, and WM with SA of Grade 1 students at Thai Christian School.

Based on the fifth research objective, there was one hypothesis: There are significant positive predictive relationships between PA, VSTM, and WM with SA of Grade 1 students at Thai Christian School such that the higher their PA, VSTM, and WM, the higher will be their SA.

**Summary of Findings**

The following findings are listed in order of the research objectives:

1. **Phonemic Awareness (PSF Task)**

   1.1 The level of PA was below the end-of-kindergarten benchmark of 33 points \((M = 24.90, SD = 12.47)\) and was classified as well-below average compared to U.S. first grade students (3\textsuperscript{rd} percentile) (Cummings et al., 2011).

   1.2 The student with the highest level of PA was in the average range (62\textsuperscript{nd} percentile) when compared to U.S. first grade students (Cummings et al., 2011).

2. **Verbal Short-Term Memory (DSF Task)**

   2.1 The level of VSTM was average (a scaled score between 0 and 0.67 SDs above the standardized mean).

   2.2 The highest level of VSTM was superior (a scaled score of 2.67 SDs above the standardized mean).
3. Working Memory (DSB Task)

3.1 The level of WM was average with a scaled score of 0 SDs from the standardized mean.

3.2 The highest level of WM was superior (a scaled score of 2 SDs above the standardized mean).

4. Spelling Achievement (PSI Task)

4.1 The level of SA, determined by both the number of words spelled correctly and from feature points, put students at an early to middle stage of letter name-alphabetic spelling, which can span from kindergarten to the middle of second grade.

4.2 The student with the highest number of words spelled correctly was classified as in the stage of within word pattern spelling, which spans first grade to the middle of fourth grade. The highest feature point scores confirmed that the highest level of development was early to middle within word pattern spelling.

5. Predictive Relationships

5.1 Performing a multiple regression found that PA, VSTM, and WM were significant predictors of SA; the model accounted for 44% of the variance in SA.

5.2 The DSB scores for WM needed a square root transformation to correct the normal distribution.

5.3 The PSI scores for SA needed a square root transformation to correct a lack of homoscedasticity.

5.4 Out of five tests for outliers, only the CVR values were outside the specified range.
Conclusions

The following conclusions were drawn from the findings of this research:

1. Mean Levels of PA, VSTM, WM, and SA
1.1 PA was much lower than U.S. first grade students on whom the PSF task was standardized (Cummings et al., 2011).
1.2 VSTM was at or slightly above an average level.
1.3 WM was at an average level.
1.4 SA was in the early to middle letter name-alphabetic stage which is within the expected range for students in kindergarten through to the middle of second grade.

2. Predictive Relationship
2.1 PA, VSTM, and WM were all significant predictors of SA with positive relationships for these Grade 1 students.
2.2 The model accounted for a moderate amount of variance in SA. PA accounted for the greatest variance, whereas VSTM and WM accounted for similar lesser amounts of variance.

Discussion

The findings are discussed for (1) the levels of phonemic awareness, verbal short-term memory, working memory, and spelling achievements, and (2) the relationship with spelling achievement.
Phonemic Awareness

To assess the level of PA, a type of phonemic segmentation task, PSF, was used. According to Adams’ (1990) hierarchy of phonemic awareness tasks, PSF is the fourth highest level of difficulty, more difficult than blending/splitting but less demanding than phoneme manipulation. The level of difficulty of the PSF task appeared to be suitable for the students as all but 4 students were able to segment words to some extent, and none of them found the task too easy since the highest score was only 70%. These results were in line with the age at which Liberman et al. (1974) found students could do this level of task and seems consistent with Adams’ (1990) position that phoneme manipulation tasks in the next difficulty level are beyond first grade students. A benefit of the PSF scoring rubric was that it allowed students to score points for partially segmenting words, otherwise scores would have been lower, possibly affecting its usefulness for this research.

Since the data available to interpret the PSF task was based upon U.S. school children, it was not surprising that native-speakers would score higher, but the level of difference was greater than anticipated. Data published for the mean PSF scores of U.S. students is shown in Table 14 (Cummings et al., 2011); the mean PSF score in this research ($M = 24.90, SD = 12.47$) was closest to the mean score of U.S. kindergarten students in their second term ($M = 28.82, SD = 17.78$) which is the age at which the PSF assessment is first used (Cummings et al., 2011).

The percentile rank of the mean score of students in this study, along with the highest score, is compared with U.S. students’ performance (Cummings et al., 2011) in each age group in Figure 9: The percentile for the mean score ranges from 41 – in the average range (25th to 74th percentile) if compared with U.S. kindergarten students, down to 3 – in the well-below average range (3rd to 8th percentile) when
compared to U.S. students at the end of grade 1. The highest scoring student in this study would be ranked as well-above average in the 96th percentile for U.S. kindergarten students, down to average in the 62nd percentile in grade 1 (Cummings et al., 2011).

**Table 14**

*Published Phoneme Segmentation Fluency (PSF) Scores From Kindergarten to Grade 1 to Compare With the Result (Cummings et al., 2011)*

<table>
<thead>
<tr>
<th>Grade Level</th>
<th>Term 1 - Fall</th>
<th>Term 2 - Winter</th>
<th>Term 3 - Spring</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$M$</td>
<td>$SD$</td>
<td>$M$</td>
</tr>
<tr>
<td>Kindergarten</td>
<td>-</td>
<td>-</td>
<td>28.82</td>
</tr>
<tr>
<td>Grade 1</td>
<td>42.01</td>
<td>16.91</td>
<td>52.66</td>
</tr>
</tbody>
</table>

*Figure 9.* Phoneme Segmentation Fluency (PSF) results compared to the criteria for percentile ranks of U.S. students at different ages (Cummings et al., 2011). The percentile ranks of the mean and highest PSF scores in this study decrease when compared with U.S. students from kindergarten (K.G.) to first grade (G.1).
The drop in the percentile when compared from kindergarten to first grade, shows that, for the U.S. students (Cummings et al., 2011), there is a considerable jump in performance over this timeframe. It seems likely that part of the explanation for the difference in performance is due to specific PA instruction of students, including intervention if students are below the benchmark level of 41% (Good & Kaminski, 2014). The PSF task has 20 alternative word lists since it is intended for tracking improvement, therefore between the first administration in kindergarten and the last in grade 1, students could gain in their fluency through practice and familiarity with the test format. Native-speakers would also have the advantage of the likelihood of being more familiar with the words in the test: students who are not familiar with the words may have to commit greater levels of resources such as VSTM and WM to the task, and they would not know if they had heard the word correctly, whereas a native speaker might be able to recall the word from long-term memory.

Although the students in this research had received instruction on phonics, which can be similar to PA tasks (Adams, 1990), they had not been trained or tested in a manner similar to the PSF task before. The novelty of the task may have made students more hesitant and reduced performance on the fluency aspect of the task. The researcher gained the impression that students were generally more confident and able to segment words in less time nearer the end of the task than nearer the beginning. Thus, if the students had been given some degree of training or practice in addition to the very brief example in the task instructions themselves, the researcher would expect the PSF scores to increase as stronger students would increase their fluency and weaker students may be more certain about correct segmentation.
Wei (2005) had found that PA in Thai primary school students transferred to English, but in this assessment the researcher noticed that features of Thai language quite often interfered with a student's ability to correctly segment certain aspects of words. Of the differences between Thai and English described by Kanokpermpoon (2007), the researcher noticed that students had particular difficulty with final consonants: either with saying the correct consonant or failing to say a final consonant at all. Vowel sounds - both long and short - also seemed tricky, which may be partly due to Thai language interference, but may just be a difficulty with producing these sounds in isolation from lack of practice (Adams, 1990).

**Verbal Short-Term Memory and Working Memory**

The VSTM and WM levels were found to be average, which was expected as, unlike IQ tests, both are relatively unaffected by prior learning (Alloway & Alloway, 2010).

One concern before beginning data collection was that the task required students to use numbers in English, which may negatively affect the results, even though the digit span tasks have a lesser linguistic demand than an alternative task (Flanagan & Kaufman, 2004). Since the results were at or slightly above the mean of the standardized sample, it seems unlikely that there was a large effect. The researcher contributes this to the students' familiarity with English numbers due to frequent use, including Math classes in English. However, it is also possible that some students with lower scores had weaker English and this limited their performance. Ideally, students could be tested in their native language to eliminate any language limitations.

Since DSF and DSB tasks can be affected by the student's attention and scores on the tasks have a lower range than the PSF or SA instruments, these tasks in
particular could benefit from additional or alternative measurements to ensure their accuracy.

**Spelling Achievement**

The Primary Spelling Inventory, which is used with kindergarten to grade 3 students, covers words representing a wide range of difficulty. The researcher expected that students would do quite well with simple consonant-vowel-consonant words that could be spelled phonetically by sounding them out, based on the phonics aspect of their English classes, but was uncertain to what extent students would be able to spell more complicated words.

The distribution of scores across the increasingly more difficult spelling features shows consistency with the developmental model of spelling on which the PSI is based: looking at Table 8, the greatest number of students scoring in each range (shown in bold) gradually shifts from 0-1 points missed for the first two features, 2-3 points missed for the third feature, 4-6 points missed for the fourth and fifth features, and all 7 points missed for the sixth to eighth features. In addition, the number of students either side of the greatest number falls off predictably, indicating development with gradual transitions and a lack of clearly-defined boundaries, as described by Bear et al. (2012). The gradual shift in the number of students in each overlapping stage of development is represented in Figure 10.
Figure 10. Development within each spelling feature. The figure shows the status of students within each spelling feature, with features ordered from left to right in terms of the expected order of development described by Bear et al. (2012).

The number of words spelled correctly and the feature point analysis gave quite consistent results, both indicating that students were, on average, in the middle of the letter name-alphabetic spelling stage of development, but the feature point analysis indicated the range could be between the early to middle stage, and this more detailed analysis should be the most accurate. Based on the mean number of feature points missed, students were classified as near to mastering initial consonants and needing further practice with final consonants and short vowels.

There was 11% of students who missed more than 3 points (indicating a need for further instruction or to study earlier features) with initial consonants who
were therefore still developing in the late emergent stage (the first step tested in the PSI); in the late emergent to early letter name-alphabetic stage (the second step) which includes final consonants, 18% missed more than 3 points; and in the early to middle letter name-alphabetic stage (the third step) which includes short vowels, 26% missed more than 3 points. For each step respectively, 69%, 46%, and 35% only missed 0-1 points (indicating they were ready to move on to learning more advanced spelling features). For the 11% who were still at the earliest stage, there is probably a need for intensive support to ensure they are able to catch up with the rest of the students in moving beyond the emergent stage. The researcher had expected more students to be at the point of moving on beyond the second and third steps; looking again at the results, there is a large drop in the number of students from those missing 2 points to those missing 3 points. It shows that most students were within 2 points of a full score for the second step (72%) and third step (61%), so students are not quite ready to move on, but they were nearer to this goal than indicated by broadening the band to include students who missed 3 points.

Looking at the later steps of development assessed on the PSI, the mean scores placed students as needing further instruction regarding digraphs and blends (fourth step) once they had mastered earlier steps; and common long vowels (fifth step), other vowels (sixth step), and inflected endings (seventh step) were well-beyond their stage of development. However, there were students who achieved scores at the level of 2-3 points missed (needing review): 22%, 12%, 4%, and 2% for step four to seven respectively. Additionally, 7% were ready to move on from the fourth step and 12% from the fifth step. Therefore, although the mean score put students at the early to middle of stage 1, typical of kindergarten or first grade U.S. students, a small percentage of students were spelling at a first to second grade level.
Considering only the specific phonics topics taught as part of the Grade 1 English curriculum (consonants, short vowels, and digraphs - see the section in Chapter II, Background of Spelling at Thai Christian School), students might have had sufficient knowledge to be able to score 7 out of 7 on initial consonants, final consonants, short vowels, and digraphs, and had the potential to spell 5 words correctly (*fan, pet, dig, rob, and gum*), giving a total PSI score of 33 points. Compared with the feature points missed in these categories, the greatest need for improvement was with digraphs, but short vowels were also slightly more problematic for students than consonants. With a mean score of 2.89 words spelled correctly on those 5 specific words, this could be expected from a lack of mastery of vowels and final consonants, making the chance of getting all three letters correct less probable. The mean PSI score was 25.11 points and 20.54 if limited to the expected features and words, equivalent to 62% of the 33 points, indicating a need to further develop these spelling skills.

It was interesting to note that the impression the researcher described earlier regarding the PSF task and difficulty with final consonants is also visible in Figure 10 when comparing initial and final consonant performance, so this may be a broader weakness connected with PA and Thai language interference, rather than spelling knowledge alone.

**Relationships with Spelling Achievement**

The proportion of variance ($R^2$) in SA explained by the three independent variables in the model was 44%, which is moderate to low. The following section explores the contribution of each variable, deviations from expectations for some individual cases, and further considerations for predicting SA.
The ratio of the beta weights - the standardized regression coefficients, in Table 12 - shows that VSTM and WM had a similar importance in predicting SA, but PA was almost three times more important. The correlations presented in Table 13 show that, for the zero-order and partial correlations, the greatest change was DSF, with a .09 decrease, which indicates that VSTM may have some prior causal or intervening effect on either one or both of PA and WM performance. The values of partial correlation (unique contribution) and part correlation (total contribution) were almost identical for the measures of VSTM and WM, also indicating their equal contributions, but PA was still more than twice as correlated.

The previous studies which were discussed in the literature review had almost all reported finding significant correlations between the independent variables in this research with spelling. PA correlations ranged from as low as .33 to .61, with an average of approximately .47 in these studies; here the zero order, partial, and part correlations for PA were .50 to .59, which are similar to other findings, but at the higher end of the range, which is similar to findings of higher correlations for second language students reported by Lafrance (2007) and with younger kindergarten and first grade students (Puranik & Alotaiba, 2012).

It is important to note that the lack of correlation between DSF and DSB ($r = .14$ and non-significant at the .05 level, which was shown in Table 9), may support the position of previous researchers (Alloway et al., 2006; Colliflower, 2013; Gathercole & Pickering, 2000) that DSB is a WM task (rather than a VSTM task) in the case of young children due to high processing requirements, rather than the case with older subjects who utilize rehearsal strategies that make greater use of VSTM instead.
Previous studies reported VSTM correlations in the range of .31 to .40, with an average of approximately .35, which is the same value as the zero-order correlation in this study, with the lowest value being the part correlation of .20.

Values for WM correlations in other research were reported as .36 and .52, with an average of .44 and in this research it was lower, .19 to .30. However, both WM correlations reported in previous research were not with spelling alone but composite literacy scores which included both spelling and reading. Explanations for a lower correlation with WM could include greater demands on WM from reading than spelling, which would be true if the reading task involved more complex processing (Milwidsky, 2009); potentially there was a lower correlation due to the difficulty of the DSB task for young students, since first grade is the youngest age where a DSB task would be used and each extra digit added to the list to be repeated makes the challenge much greater (Weiss et al., 2006); and students may be under-utilizing WM if they are relying more on a sublexical approach to spelling of converting sounds to letters, than also considering lexical information: meaning and knowledge of spelling frequencies/patterns (Rapp et al., 2002).

Overall, PA and VSTM had similar levels of correlation with SA as reported by other studies. WM correlation was lower, possibly due to SA being assessed in isolation rather than as a part of a literacy measure, or possibly due to the difficulty of the DSB task for young students.

**Outliers.** Five tests of outliers were checked, and the CVR values indicated outliers in 15 cases; in about half these cases, they were near the borderline, as shown in the figure for covariance ratio against case number in Appendix G. The other figures in the appendix compare the CVR outliers against the four other outlier tests to identify relatively large values. The Mahalanobis distance shows the same
distribution of outliers as CVR, but CVR identified outliers due to a narrower range. The case numbers of CVR outliers which were also relatively large outliers on other tests - although they were within the given limits - are summarized at the end of Appendix G. Ideally, data from a larger sample could be collected to provide more data points at the upper and lower ends of each scale to more accurately study outliers.

Using the plot of predicted SA against actual performance, shown in Figure 7, the researcher studied the data for common features that related to performance that was higher or lower than expected: based on the regression model, students above the line were predicted to have been able to spell better than their actual performance, and those below the line performed better than might be expected. The following observations were made: (1) There were 5 cases of low SA where students were expected to score higher because they had relatively good PSF scores of 12 - 30 points (for the whole study, $M = 24.90, SD = 12.47$) - their DSF scores (5 - 8 points) and DSB scores (4 - 6 points) were not unusual; (2) There were 5 cases of low SA where students scored higher than expected because they had relatively poor PSF scores (0 - 6) and their DSB scores were low (0 - 4) but their DSF scores (5 - 8) were similar to other cases with this level of SA; (3) There were 2 cases of high SA where students were expected to score higher, that had good DSF scores (10 and 12) and the higher of the two predictions was also due to a high PSF of 47; (4) There were 4 cases where students with high SA scored higher than expected, and, curiously, with the exception of 1 student who had a very high DSF of 13 points, their scores were all very similar, with a surprisingly low PSF of 26 - 27, and with average scores for DSF (8 points) and DSB scores (5-6 points) at most only 1 point above average.
**Low Spelling Achievement.** Students with low SA but normal PA seemed to lack phonics skills to write the sounds they heard (e.g., *fan = flv, dig = dye, rob = lory*). Students with low SA and low PA seemed unable to spell little more than the first letter of a word and perhaps a vowel, if at all (e.g., *dig = den, rob = ron, stick = bet*).

**High Spelling Achievement.** Students with high SA and high PA scores may have mastered earlier spelling stages and be capable of moving on, but are yet to have learned sufficient knowledge to make that step. For example, 2 students only scored 1 or 2 feature points on *common long vowels*, but had almost all full scores on features in earlier stages. Students with high SA but low PA managed to perform better than predicted - their fluency may have been sufficiently high for these non-time-limited spelling tasks and previous research indicated that PA may be less correlated with older students where phonics becomes less important as students transition to higher stages of spelling development; 4 students in this category were mostly scoring 3 or 4 feature points for *common long vowels and other vowels*, putting them in the middle of the third stage, within word pattern spelling, although 2 of the lower scoring students needed more practice with digraphs (stage 2, letter name-alphabetic spelling) as they still made some mistakes such as interchanging *ch* and *sh*.

**Feedback on Unusual Cases.** Again referring to the plot of predicted SA against actual performance (Figure 7), the researcher made a list of cases with lower scores and higher scores, particularly if further away from the line of best fit, to investigate further. The homeroom teachers were asked to comment on any factors they were aware of that might have contributed to the child's SA; the researcher also listed comments for students from his class. The teachers wrote comments without
looking at the scores to try to keep comments from being biased. The next two paragraphs contain observations regarding those comments, which could help explain unusual SA for some cases.

For students with low SA that had higher predictions, 2 students tried hard with schoolwork but still seemed to struggle - which indicates a general learning difficulty, and 3 students had difficulty paying attention in class - which could be expected to limit the impact of instruction. For those with low SA but higher performance than expected, there were 3 students who were reported to be weak students that made noticeable improvements near the end of the year - they seemed to be late developers and their SA may not have had time to catch-up with other observed improvements.

For students with high SA, it was difficult to generalize about lower or higher than expected performance, but, overall, students with higher SA were reported to be good spellers from the start of the year (2 students), had a native English speaking parent or Thai parent who spoke English well (4 students) and 1 student always achieved full scores on weekly spelling tests - indicating parental support with learning spelling words for homework.

**Further Finding: Trends in Spelling Achievement.** The boxplots in Figure 8 displayed some interesting trends which may have practical relevance in the classroom. Lower levels of either or both VSTM and WM do not seem to limit students to low SA, however, no student in these groupings scored above 40 on the PSI, compared with 10 students with both high VSTM and WM who scored 44 - 58 points, which could indicate this is advantageous in spelling development.

Low levels of PA alone also did not appear to limit SA, however low PA groups contained some of the lowest SA scores. In combination with memory levels,
there are some pronounced trends. Low VSTM and WM, students performed around 10 points better with each increase in the level of PA; students with the combination of low PA, VSTM, and WM had very low SA. Medium and high PA level groups with high VSTM and WM had the highest SA, but the medium and high groups had similar scores; in contrast, the low PA group performance was much lower, similar to the low PA-low VSTM/WM group or medium PA-low VSTM&WM group.

**Model Improvements.** Although the PSF task that was used was a reliable instrument, an alternative for measuring PA which is not timed may be more consistent with SA, since there were no time limits for the PSI task and some of the highest spellers did not have particularly high PSF scores, since scores can reflect speed as much as accuracy, yet in this study spelling is focused on accuracy.

Since the model could only account for 44% of the variance in SA, a more complete model would need to include additional predictors. Likely to be next biggest predictor is letter-sound knowledge - i.e., phonics - since the accurate representation of sounds requires knowledge of the most common sound represented by a letter and when it may produce other sounds. Carrying out this type of assessment would require great care to accept any possible correct sound (Treiman et al., 1998).

Another possible inclusion in the model is reading ability as an indication of exposure to printed text, the amount the student reads, since correlations have been reported between reading and spelling (Bear et al., 2012), emergent spellers base their writing on properties of text they have seen (Pollo, 2008) and vocabulary size is connected to both spelling and reading (Invernizzi & Hayes, 2004).

A further addition could be the importance of visual memory: visuospatial short-term memory. There is very little literature which directly relates spelling with visual learning, yet Alloway et al. (2006) indicated that 4-6 year-old children make
greater use of this resource. It might help to explain cases such as with students who are weaker in VSTM or PA, but have a higher SA than expected.

This research investigated linear predictive relationships with SA, but a nonlinear model may fit better, particularly with very low or high SA, and may address the issue of a lack of homoscedasticity that needed to be corrected.

**Implications.** The relative importance of the independent variables in the model are interesting, not because they were found to be significant predictors, which could reasonably have been expected from previous research, but that the dependence on VSTM and WM memory resources were much less important than ability with PA - to think about units of sounds in a word. From a teaching point of view, this is good news, as it has already been seen that large increases in PA appear to be possible during the last year of kindergarten and first grade if students practice and, if necessary, receive intensive support to meet benchmark levels (Good & Kaminski, 2014); in contrast, memory capacities are more difficult to change as they are relatively unaffected by prior learning (Alloway & Alloway, 2010).

**Recommendations**

The following recommendations for teachers, administrators and future research are based on the findings of this research.

**Recommendations for Teachers**

Students' phonemic awareness alone was able to account for 25% of the variation in spelling achievement (just over half of the 44% variance in the model). Students who are weak in SA can struggle with even the earliest stages of spelling development. Students do not necessarily need a high level of PA to spell well, but it
appears to be advantageous. Students can learn and practice skills required for PA specifically, not only letter-sound correspondence which is taught through phonics. This has the potential to considerably increase the ability of students to accurately and quickly identify sounds in words. It should also be noted that differences between Thai and English appear to be problematic for students when trying to segment words.

The separate contributions of verbal short-term memory and working memory to SA were of very similar levels, and in total, they could account for 22% of the variation in SA (half of the 44% variance in the model). The mean levels of VSTM and WM in a sample should be close to those expected for that age, however, individual levels can vary greatly. Lower levels of VSTM and WM alone are not necessarily barriers to good SA, but, in combination with low PA, such students could be expected to have very low SA. Conversely, students with high VSTM and WM in combination with medium to high levels of PA may have the highest SA potential.

If a student has low PA, VSTM, and WM, they are likely to need extra support to improve their SA, as they will probably struggle to sound out letters when practicing on their own. Other research (Alloway & Alloway, 2010; Alloway et al., 2006) has identified poor WM as contributing to a long-term failure to learn.

Some students can benefit from further practice in early spelling features, specifically final consonants and short vowels, and these should be mastered before providing additional instruction on digraphs, which were much more challenging for most students. Students had a similar level of knowledge of blends as digraphs, even though these had not been specifically taught, but, again, earlier features need to be mastered before moving on to this. A developmental spelling test such as the PSI can provide useful insights into students' spelling achievement outside of the context of weekly spelling tests.
Recommendations for Administrators

In some schools systems, spelling tests have fallen out of favor, but this research highlighted the wide range of spelling development which can exist among students in the same grade level. The range suggests that differentiated levels of spelling instruction could be used, even with young non-native English speakers, as some students may still require more practice with early spelling features while others may have mastered those and more.

In addition to phonics instruction, phonemic awareness (PA) can be taught from a very young age as easier PA tasks than the segmentation one used in this study are also available. Beginning PA in kindergarten may be necessary to provide time for improvement and support the transition from emergent to letter-name alphabetic stages so that students can be ready to move on to the within word pattern stage by the end of first grade. Low PA may be problematic for spelling achievement, so a minimum standard could be set to identify students in need of extra support.

A spelling program which is based on developmental stages of spelling could be the most time-efficient way of helping students, as findings in this research were in agreement with an orderly progression through specific stages of development.

Recommendations for Future Research

The instruments used for this research were suitable, but could be made more suitable with some modifications:

1. The fluency aspect of the PSF task may not have been the best way to measure PA since fluency could obscure a lack of accuracy (or vice versa), students may speed up as the test progresses, and the spelling assessment was not time-limited;
an alternative would be to test a set number of words without a time restriction,
and, whether timed or not, a training session could enable students to perform
nearer their full potential on the first assessment.

2. The PSF task used words which may or may not be familiar to students, which
may give an unfair advantage to some. Substituting the word list for one with
made-up words could help to eliminate the possible benefit of segmenting words
within the student's vocabulary.

3. Digit span tasks could be performed in a student's native language where possible
to ensure they can demonstrate their full ability.

4. Digit span tasks could be repeated at a later date or the number of trials at each
length could be increased to ensure that the assessment was accurate and not
affected by a momentary lapse in concentration or other temporary condition.

To develop a more complete model of spelling achievement, additional
factors could be investigated: (1) The contribution of letter-sound knowledge could be
studied, as it connects PA with written spelling. (2) An ability with which spelling has
been linked in the literature is reading; time spent reading may help students improve
their vocabulary size and acquire knowledge of spelling patterns. (3) A third type of
memory might also be considered: visuospatial short-term memory, which may be
more important with students in first grade or younger who are less reliant on verbal
rehearsal strategies. (4) A students' first language or languages spoken at home. (5)
Parental involvement and/or the time spent on spelling homework. Alternative models
could be investigated using methods such as a nonlinear multiple regression analysis.
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http://doi.org/10.1080/10862969509547876


http://doi.org/10.5709/acp-0179-6


APPENDIX A

Phoneme Segmentation Fluency

Directions for Administration

Instrument: Progress Monitoring 15
Directions for Administration

1. Place examiner probe on clipboard and position so that student cannot see what you record.

2. Say these specific directions to the student:

   **I am going to say a word. After I say it, you tell me all the sounds in the word. So, if I say, “sam,” you would say /s/ /a/ /m/. Let’s try one.** (one second pause) **Tell me the sounds in “mop”.**

   \[
   \begin{array}{|c|c|}
   \hline
   \text{CORRECT RESPONSE:} & \text{INCORRECT RESPONSE:} \\
   \text{If student says, /m/ /o/ /p/, you say} & \text{If student gives any other response, you say,} \\
   \text{Very good. The sounds in} & \text{The sounds in “mop” are /m/ /o/ /p/.} \\
   \text{“mop” are /m/ /o/ /p/.} & \text{Your turn. Tell me the sounds in “mop”.} \\
   \hline
   \end{array}
   \]

   **OK. Here is your first word.**

3. Give the student the first word and start your stopwatch. If the student does not say a sound segment after 3 seconds, give him/her the second word and score the first word as zero segments produced.

4. As the student says the sounds, mark the student response in the scoring column. Underline each different, correct, sound segment produced. Put a slash (/) through sounds produced incorrectly.

5. As soon as the student is finished saying the sounds, present the next word promptly and clearly.

6. The maximum time for each sound segment is 3 seconds. If the student does not provide the next sound segment within 3 seconds, give the student the next word. If student provides the initial sound only, wait 3 seconds for elaboration.

7. At the end of 1 minute, stop presenting words and scoring further responses. Add the number of sound segments produced correctly. Record the total number of sound segments produced correctly on the bottom of the scoring sheet.

Directions for Scoring

1. **Discontinue rule.** If a student has not given any sound segments correctly in the first 5 words, discontinue the task and put a score of zero (0).

2. Underline the sound segments in the word the student produces that are correctly pronounced. Students receive 1 point for each different, correct, part of the word.

3. Put a slash (/) through segments pronounced incorrectly.
4. **Correct Segmentation:** A correct sound segment is any different, correct, part of the word represented by sounds that correspond to the word part. For example, the sound /t/ is a correct sound segment of “trick,” as are /tr/ and /tri/ (see rule 10, Incomplete Segmentation).

<table>
<thead>
<tr>
<th>WORD:</th>
<th>STUDENT SAYS:</th>
<th>SCORING PROCEDURE:</th>
<th>CORRECT SEGMENTS:</th>
</tr>
</thead>
<tbody>
<tr>
<td>trick</td>
<td>“t...r...i...k”</td>
<td>/t/ /r/ /i/ /k/</td>
<td><strong>4 /4</strong></td>
</tr>
<tr>
<td>cat</td>
<td>“k...a...t”</td>
<td>/k/ /a/ /t/</td>
<td><strong>3 /3</strong></td>
</tr>
</tbody>
</table>

5. **Schwa sounds.** Schwa sounds (/u/) added to consonants are not counted as errors. Some phonemes cannot be pronounced correctly in isolation without a vowel, and some early learning of sounds includes the schwa. For example, if the word is “trick” and the student says “tu...ru...i...ku” they would receive 4 of 4 points.

<table>
<thead>
<tr>
<th>WORD:</th>
<th>STUDENT SAYS:</th>
<th>SCORING PROCEDURE:</th>
<th>CORRECT SEGMENTS:</th>
</tr>
</thead>
<tbody>
<tr>
<td>trick</td>
<td>“tu...ru...i...ku”</td>
<td>/t/ /u/ /i/ /k/</td>
<td><strong>4 /4</strong></td>
</tr>
<tr>
<td>cat</td>
<td>“ku...a...tu”</td>
<td>/k/ /u/ /a/ /t/</td>
<td><strong>3 /3</strong></td>
</tr>
</tbody>
</table>

6. **Additions.** Additions are not counted as errors if they are separated from the other sounds in the word. For example, if the word is “trick,” and the student says “t...r...i...ck...s,” they would receive 4 of 4 points.

<table>
<thead>
<tr>
<th>WORD:</th>
<th>STUDENT SAYS:</th>
<th>SCORING PROCEDURE:</th>
<th>CORRECT SEGMENTS:</th>
</tr>
</thead>
<tbody>
<tr>
<td>trick</td>
<td>“t...r...i...ck...s”</td>
<td>/t/ /r/ /i/ /k/</td>
<td><strong>4 /4</strong></td>
</tr>
<tr>
<td>cat</td>
<td>“s...c...a...t”</td>
<td>/s/ /s/ /a/ /t/</td>
<td><strong>3 /3</strong></td>
</tr>
</tbody>
</table>

7. **Articulation and dialect.** The student is not penalized for imperfect pronunciation due to dialect, articulation, or second language interference. For example, if the student consistently says /θ/ for /s/, and he or she says, /ɛr/ /ɛ/ /θɛ/ /θ/ for “rest,” he or she should be given credit for correct segmentation. This is a professional judgment and should be based on the student’s responses and any prior knowledge of his/her speech patterns.

<table>
<thead>
<tr>
<th>WORD:</th>
<th>STUDENT SAYS:</th>
<th>SCORING PROCEDURE:</th>
<th>CORRECT SEGMENTS:</th>
</tr>
</thead>
<tbody>
<tr>
<td>rest</td>
<td>“r...ɛ...θ...t”</td>
<td>/r/ /ɛ/ /s/ /θ/</td>
<td><strong>4 /4</strong></td>
</tr>
</tbody>
</table>
8. **Sound elongation.** The student may elongate the individual sounds and run them together as long as it is clear he or she is aware of each sound individually. For example, if the student says, "rrrrreeeeessssstttt," with each phoneme held long enough to make it clear they know the sounds in the word, they would receive credit for 4 phonemes correct. This is a professional judgment and should be based on the student’s responses and prior knowledge of the student’s instruction. When in doubt, no credit is given.

<table>
<thead>
<tr>
<th>WORD</th>
<th>STUDENT SAYS</th>
<th>SCORING PROCEDURE</th>
<th>CORRECT SEGMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>rest</td>
<td>“rrrrreeeeeessssstttt”</td>
<td>/r/ /e/ /s/ /t/</td>
<td>4 /4</td>
</tr>
</tbody>
</table>

9. **No segmentation:** If the student repeats the entire word, no credit is given for any correct parts. For example, if the word is “trick,” and the student says “trick” circle the word and give 0 points.

<table>
<thead>
<tr>
<th>WORD</th>
<th>STUDENT SAYS</th>
<th>SCORING PROCEDURE</th>
<th>CORRECT SEGMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>trick</td>
<td>“trick”</td>
<td>/t/ /r/ /i/ /k/</td>
<td>0 /4</td>
</tr>
<tr>
<td>cat</td>
<td>“cat”</td>
<td>/k/ /a/ /t/</td>
<td>0 /3</td>
</tr>
</tbody>
</table>

10. **Incomplete segmentation:** The student is given credit for each correct sound segment, even if they have not segmented to the phoneme level. Use the underline to indicate the size of the sound segment. For example, if the word is “trick,” and the student says “tr...ick,” they would receive 2 or four points.

<table>
<thead>
<tr>
<th>WORD</th>
<th>STUDENT SAYS</th>
<th>SCORING PROCEDURE</th>
<th>CORRECT SEGMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>trick</td>
<td>“tr...ick”</td>
<td>/t/ /r/ /i/ /k/</td>
<td>2 /4</td>
</tr>
<tr>
<td>cat</td>
<td>“c...at”</td>
<td>/k/ /a/ /t/</td>
<td>2 /3</td>
</tr>
</tbody>
</table>

11. **Overlapping segmentation:** The student receives credit for each different, correct, sound segment of the word. Thus, if the word is “trick,” and the student says “tr...ick,” the student would receive 2 of 4 points because /tri/ and /ick/ are both different, correct, sound segments of “trick.”

<table>
<thead>
<tr>
<th>WORD</th>
<th>STUDENT SAYS</th>
<th>SCORING PROCEDURE</th>
<th>CORRECT SEGMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>trick</td>
<td>“tri...ick”</td>
<td>/t/ /r/ /i/ /k/</td>
<td>2 /4</td>
</tr>
<tr>
<td>cat</td>
<td>“ca...a...at”</td>
<td>/k/ /a/ /a/</td>
<td>3 /3</td>
</tr>
</tbody>
</table>
12. **Omissions:** The student does not receive credit for sound segments that are not produced. If the student provides the initial sound only, be sure to wait 3 seconds for elaboration. For example, if the word is “trick,” and the student says “tr” you must wait 3 seconds before presenting the next word (see 3 second rule).

<table>
<thead>
<tr>
<th>WORD</th>
<th>STUDENT SAYS:</th>
<th>SCORING PROCEDURE:</th>
<th>CORRECT SEGMENTS:</th>
</tr>
</thead>
<tbody>
<tr>
<td>trick</td>
<td>“tr...(3 seconds)”</td>
<td>/t/ /r/ /i/ /k/</td>
<td>1/4</td>
</tr>
<tr>
<td>cat</td>
<td>“c...t”</td>
<td>/k/ /a/ /t/</td>
<td>2/3</td>
</tr>
</tbody>
</table>

13. **Segment mispronunciation:** The student does not receive credit for sound segments that are mispronounced. For example, if the word is “trick,” and the student says “t...r...i...ks” they would receive no credit for /ks/ because there is no /ks/ sound segment in the word “trick.”

<table>
<thead>
<tr>
<th>WORD</th>
<th>STUDENT SAYS:</th>
<th>SCORING PROCEDURE:</th>
<th>CORRECT SEGMENTS:</th>
</tr>
</thead>
<tbody>
<tr>
<td>trick</td>
<td>“t...r...i...ks”</td>
<td>/t/ /r/ /i/ /k/</td>
<td>3/4</td>
</tr>
<tr>
<td>cat</td>
<td>“b...a...t”</td>
<td>/k/ /a/ /t/</td>
<td>2/3</td>
</tr>
</tbody>
</table>
Progress Monitoring 15
Phoneme Segmentation Fluency

hunt /h/ /u/ /n/ /t/  school /s/ /k/ /oo/ /l/  ___/8
said /s/ /e/ /d/  them /TH/ /e/ /m/  ___/6
mean /m/ /ea/ /n/  late /l/ /ai/ /t/  ___/6
chuck /ch/ /u/ /k/  pat /p/ /a/ /t/  ___/6
pouch /p/ /ow/ /ch/  job /j/ /o/ /b/  ___/6
chase /ch/ /ai/ /s/  check /ch/ /e/ /k/  ___/6
here /h/ /ea/ /r/  rides /r/ /ie/ /d/ /z/  ___/7
skate /s/ /k/ /ai/ /t/  list /l/ /i/ /s/ /t/  ___/8
game /g/ /ai/ /m/  tank /t/ /a/ /ng/ /k/  ___/7
help /h/ /e/ /l/ /p/  coal /k/ /oa/ /l/  ___/7
lock /l/ /o/ /k/  eight /ai/ /t/  ___/5
hide /h/ /ie/ /d/  points /p/ /oi/ /n/ /t/ /s/ ___/8

Error Pattern:

Total: ___
APPENDIX B

Digit Span

Digit Span Script (Forward and Backward)

Digit Span Record Form (Forward and Backward)

Digit Span Scoring
Digit Span Task Script

**Forward**
I am going to say some numbers. Listen carefully, and when I am through, say them right after me. Just say what I say.

**Practice 1:**
When I say 4, what do you say?
- If child is correct [4]: say, “That’s right”, and proceed to practice item 2.
- If child is incorrect say, “That’s not quite right. When I say 4, I want you to say 4. So, when I say 4, what do you say? Allow child to respond.
- Correct Response [4]: say “That’s right”, and proceed to practice item 2.
- Incorrect Response: say, “That’s not quite right. When I say 4, I want you to say 4. Let’s try another one”. Proceed to practice item 2 (do not repeat practice item again).

**Practice 2:**
When I say 7-3, what do you say?
- If child is correct [7-3]: say, “That’s right”, and proceed to practice item 2.
- If child is incorrect say, “That’s not quite right. When I say 7-3, I want you to say 7-3. Let’s try some others.

**Test Items:**
Give both trials of each item, even if trial 1 is answered correctly. Only stop after child answers both trials incorrectly.

<table>
<thead>
<tr>
<th>Trial 1</th>
<th>Trial 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-9</td>
<td>4-6</td>
</tr>
<tr>
<td>3-8-6</td>
<td>6-1-2</td>
</tr>
<tr>
<td>3-4-1-7</td>
<td>6-1-5-9</td>
</tr>
<tr>
<td>8-4-2-3-9</td>
<td>5-2-1-8-6</td>
</tr>
<tr>
<td>3-8-9-1-7-4</td>
<td>7-9-6-4-8-3</td>
</tr>
<tr>
<td>5-1-7-4-2-3-8</td>
<td>9-8-5-2-1-6-3</td>
</tr>
<tr>
<td>1-8-4-5-9-7-6-3</td>
<td>2-9-7-6-3-1-5-4</td>
</tr>
<tr>
<td>5-3-8-7-1-2-4-6-9</td>
<td>4-2-6-9-1-7-8-3-5</td>
</tr>
</tbody>
</table>

Do not repeat any trial item. If child asks you to repeat a trial, say “Just take your best guess”.


Backward

Practice 1

Now I am going to say some more numbers, but this time when I stop, I want you to say them backward. If I say 8-2, what would you say?

If child is correct [2-8]: say, “That’s right”, and proceed to practice item 2.
If child is incorrect say, “That’s not quite right. I said 8-2, so to say it backward, you should say 2-8.” Let’s try again: 8-2. Allow child to respond.
Correct Response [2-8]: say “That’s right”, and proceed to practice item 2.
Incorrect Response: say, “That’s not quite right. I said 8-2, so to say it backward, you should say 2-8”. Proceed to practice item 2 (do not repeat practice item again).

Practice 2

Let’s try these numbers. Remember, you are to say them backward: 5-6

If child is correct [6-5]: say, “That’s right”, and proceed to the test items.
If child is incorrect say, “That’s not quite right. I said 5-6, so to say it backward, you should say 6-5. Let’s try that again: 5-6.
Correct Response [6-5]: say, “That’s Right”. Proceed to Test Item 1
Incorrect Response: say, “That’s not quite right. I said 5-6, so to say it backward, you should say 6-5. Proceed to Test Item 1 (do not repeat practice item again).

Test Items:
Give both trials of each item, even if trial 1 is answered correctly. Only stop after child answers both trials incorrectly. Do not give any further directions.

<table>
<thead>
<tr>
<th>Trial 1</th>
<th>Trial 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-1</td>
<td>1-3</td>
</tr>
<tr>
<td>3-5</td>
<td>6-4</td>
</tr>
<tr>
<td>5-7-4</td>
<td>2-5-9</td>
</tr>
<tr>
<td>7-2-9-6</td>
<td>8-4-9-3</td>
</tr>
<tr>
<td>4-1-3-5-7</td>
<td>9-7-8-5-2</td>
</tr>
<tr>
<td>1-6-5-2-9-8</td>
<td>3-6-7-1-9-4</td>
</tr>
<tr>
<td>8-5-9-2-3-4-6</td>
<td>4-5-7-9-2-8-1</td>
</tr>
<tr>
<td>6-9-1-7-3-2-5-8</td>
<td>3-1-7-9-5-4-8-2</td>
</tr>
</tbody>
</table>

Do not repeat any trial item. If child asks you to repeat a trial, say “Just take your best guess”.
Digit Span Record Form (Forward and Backward) (Meador et al., 2013; Wechsler, 2003)

Digit Span Record Form

Give both trials of each item, even if trial 1 is answered correctly. Only stop after child answers both trials in one row incorrectly.

Practice 1:

<table>
<thead>
<tr>
<th></th>
<th>Practice 1</th>
<th>Response</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trial 1</td>
<td></td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Trial 2</td>
<td></td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

Practice 2:

<table>
<thead>
<tr>
<th></th>
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<th>Response</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trial 1</td>
<td></td>
<td>7-3</td>
<td></td>
</tr>
</tbody>
</table>

Forward Test Items:

<table>
<thead>
<tr>
<th>Trial 1</th>
<th>Response</th>
<th>Score</th>
<th>Trial 2</th>
<th>Response</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-9</td>
<td></td>
<td></td>
<td></td>
<td>4-6</td>
<td></td>
</tr>
<tr>
<td>3-8-6</td>
<td></td>
<td></td>
<td></td>
<td>6-1-2</td>
<td></td>
</tr>
<tr>
<td>3-4-1-7</td>
<td></td>
<td></td>
<td></td>
<td>6-1-5-8</td>
<td></td>
</tr>
<tr>
<td>8-4-2-3-9</td>
<td></td>
<td></td>
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<td>5-2-1-8-6</td>
<td></td>
</tr>
<tr>
<td>3-8-9-1-7-4</td>
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<td></td>
<td></td>
<td>7-9-6-4-8-3</td>
<td></td>
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<tr>
<td>5-1-7-4-2-3-8</td>
<td></td>
<td></td>
<td></td>
<td>9-8-5-2-1-6-3</td>
<td></td>
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<td>1-8-4-5-9-7-6-3</td>
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<td>2-9-7-6-3-1-5-4</td>
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<tr>
<td>5-3-8-7-1-2-4-6-9</td>
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<td></td>
<td></td>
<td>4-2-6-9-1-7-8-3-5</td>
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</table>
### Backward:

#### Practice 1:

<table>
<thead>
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<th>Response</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>8-2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Trial 2</th>
<th>Practice 1</th>
<th>Response</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>8-2</td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

#### Practice 2:

<table>
<thead>
<tr>
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<th>Practice 2</th>
<th>Response</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5-6</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Trial 2</th>
<th>Practice 2</th>
<th>Response</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5-6</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Test Items:

Give both trials of each item, even if trial 1 is answered correctly. Only stop after child answers both trials incorrectly.

<table>
<thead>
<tr>
<th>Trial 1</th>
<th>Response</th>
<th>Score</th>
<th>Trial 2</th>
<th>Response</th>
<th>Score</th>
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</thead>
<tbody>
<tr>
<td>2-1</td>
<td></td>
<td>1-3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3-5</td>
<td></td>
<td>6-4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5-7-4</td>
<td></td>
<td>2-5-9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7-2-9-6</td>
<td></td>
<td>8-4-9-3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4-1-3-5-7</td>
<td></td>
<td>9-7-8-5-2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-6-5-2-9-8</td>
<td></td>
<td>3-6-7-1-9-4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8-5-9-2-3-4-6</td>
<td></td>
<td>4-5-7-9-2-8-1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6-9-1-7-3-2-5-8</td>
<td></td>
<td>3-1-7-9-5-4-8-2</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Digit Span Scoring (Meador et al., 2013; Wechsler, 2003)

Digit Span Scoring

Each item is coded as follows:

- For each test item (forward and backward), the child gets 1 point for each number sequence they recall correctly. For example, if a child was given the sequence 587 to recall backwards and they said 875, they would get a score of 0 for that item. If they said 785, they would get a score of 1 for that item.

Final Score:

- The longest span correctly recalled across the test items (9 possible for forward and 8 possible for backward). Look for the highest test item with at least one trial that contains a score of “1” to locate the longest span recalled correctly. Obtain a final score for the forward and backward series separately.
APPENDIX C

Primary Spelling Inventory

General Directions

Teacher's Administration Notes

Student Answer Sheet

Feature Guide for Scoring
General Directions for Administering the Words Their Way Inventories

Students should not study the words in advance of testing. Assure students that they will not be graded on this activity, and that they will be helping you plan for their needs. Following is a possible introduction to the assessment.

I am going to ask you to spell some words. Spell them the best you can. Some of the words may be easy to spell; some may be difficult. When you do not know how to spell a word, spell it the best you can.

Ask students to number their paper (or prepare a numbered paper for kindergarten or early first grade). Call each word aloud and repeat it. Say each word naturally, without emphasizing phonemes or syllables. Use it in a sentence, if necessary, to be sure students know the exact word. Sample sentences are provided along with the words. After administering the inventory, use a Feature Guide, Class Composite Form, and, if desired, a Spelling-by-Stage Classroom Organization Chart to complete your assessment. Error Guide forms for the Primary and Elementary Inventories are available at PDTOOLKIT for Words Their Way. The online assessment application will help complete the feature guide and create a class composite automatically.

Scoring the Inventory Using the Feature Guides

1. To score by hand, make a copy of the appropriate Feature Guide (PSI p. 316, ESI p. 320, USI p. 323) for each student. Draw a line under the last word used if you called fewer than the total number and adjust the possible total points at the bottom of each feature column.

2. Score the words by checking off the features spelled correctly that are listed in the cells to the right of each word. For example, if a student spells bed as BAD, he gets a check in the initial b cell and the final d cell, but not for the short vowel. Write in the vowel used (a, in this case), but do not give any points for it. If a student spells train as TRANE, she gets a check in the initial r cell and the final n cell, but not for the long vowel pattern. Write in the vowel pattern used (u-e in this case), but do not give any points for it. Put a check in the “Correct” column if the word is spelled correctly. Do not count reversed letters as errors but note them in the cells. If unnecessary letters are added, give the speller credit for what is correct (e.g., if bed is spelled BEDE, the student still gets credit for representing the consonants and short vowel), but do not check “Correct” spelling.

3. Add the number of checks under each feature and across each word, double-checking the total score recorded in the last cell. Modify the ratios in the last row depending on the number of words called aloud.

Interpreting the Results of the Spelling Inventory

1. Look down each feature column to determine instructional needs. Students who miss only one (or two, if the features sample 8 to 10 words) can go on to other features. Students who miss two or three need some review work; students who miss more than three need careful instruction on this feature. If a student did not get any points for a feature, earlier features need to be studied first.

2. To determine a stage of development, note where students first make two or more errors under the stages listed in the shaded box at the top of the Feature Guide. Circle this stage.

3. Raw scores or total number correct can also be used as a guide to calling the stage. Refer to the chart on page 34.
Primary Spelling Inventory: Teacher's Administration Notes

Introduction:
"I will ask you to spell some words. Spell them the best you can. Some words may be easy to spell; some may be difficult. When you do not know how to spell a word, spell it the best you can."

Administration:
Say the words aloud by pronouncing each word naturally without drawing out the sounds or breaking it into syllables. Leave this for students to do. Say each word twice (leave a 3 second gap). Wait for all students to finish writing before proceeding to the next word.

<table>
<thead>
<tr>
<th>#</th>
<th>Word</th>
<th>#</th>
<th>Word</th>
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<tr>
<td>1</td>
<td>fan</td>
<td>14</td>
<td>fright</td>
</tr>
<tr>
<td>2</td>
<td>pet</td>
<td>15</td>
<td>chewed</td>
</tr>
<tr>
<td>3</td>
<td>dig</td>
<td>16</td>
<td>crawl</td>
</tr>
<tr>
<td>4</td>
<td>rob</td>
<td>17</td>
<td>wishes</td>
</tr>
<tr>
<td>5</td>
<td>hope</td>
<td>18</td>
<td>thorn</td>
</tr>
<tr>
<td>6</td>
<td>wait</td>
<td>19</td>
<td>shouted</td>
</tr>
<tr>
<td>7</td>
<td>gum</td>
<td>20</td>
<td>spoil</td>
</tr>
<tr>
<td>8</td>
<td>sled</td>
<td>21</td>
<td>growl</td>
</tr>
<tr>
<td>9</td>
<td>stick</td>
<td>22</td>
<td>third</td>
</tr>
<tr>
<td>10</td>
<td>shine</td>
<td>23</td>
<td>camped</td>
</tr>
<tr>
<td>11</td>
<td>dream</td>
<td>24</td>
<td>tries</td>
</tr>
<tr>
<td>12</td>
<td>blade</td>
<td>25</td>
<td>clapping</td>
</tr>
<tr>
<td>13</td>
<td>coach</td>
<td>26</td>
<td>riding</td>
</tr>
</tbody>
</table>
Student Answer Sheet

Name: ___________________  Number: ____  G.1/____

1. ______________________
2. ______________________
3. ______________________
4. ______________________
5. ______________________
6. ______________________
7. ______________________
8. ______________________
9. ______________________
10. ______________________
11. ______________________
12. ______________________
13. ______________________
14. ______________________
15. ______________________
16. ______________________
17. ______________________
18. ______________________
19. ______________________
20. ______________________
21. ______________________
22. ______________________
23. ______________________
24. ______________________
25. ______________________
26. ______________________
# Words Their Way Primary Spelling Inventory Feature Guide

**Student's Name: ___________________________**

**Teacher: _____________________________**

**Grade: ____**

**Date: ____**

**Words Spelled Correctly: ____ / 26**

**Feature Points: ____ / 56**

**Total: ____ / 82**

**Spelling Stage: ____

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<tr>
<th>SPELLING STAGES</th>
<th>EMERGENT</th>
<th>LETTER NAME=ALPHABETIC</th>
<th>WITHIN WORD PATTERN</th>
<th>SYLLABLES AND AFFIXES</th>
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</thead>
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<tr>
<td>Features →</td>
<td>LATE</td>
<td>EARLY</td>
<td>MIDDLE</td>
<td>LATE</td>
</tr>
<tr>
<td>Consonants</td>
<td>Initial</td>
<td>Final</td>
<td>Short Vowels</td>
<td>Digraphs</td>
</tr>
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<td>f</td>
<td>n</td>
<td>a</td>
<td></td>
</tr>
<tr>
<td>2. pet</td>
<td>p</td>
<td>t</td>
<td>e</td>
<td></td>
</tr>
<tr>
<td>3. dig</td>
<td>d</td>
<td>g</td>
<td>i</td>
<td></td>
</tr>
<tr>
<td>4. rob</td>
<td>r</td>
<td>b</td>
<td>o</td>
<td></td>
</tr>
<tr>
<td>5. hope</td>
<td>h</td>
<td>p</td>
<td>o-e</td>
<td></td>
</tr>
<tr>
<td>6. wait</td>
<td>w</td>
<td>t</td>
<td>ai</td>
<td></td>
</tr>
<tr>
<td>7. gum</td>
<td>g</td>
<td>m</td>
<td>u</td>
<td></td>
</tr>
<tr>
<td>8. sled</td>
<td>e</td>
<td></td>
<td>sl</td>
<td></td>
</tr>
<tr>
<td>9. stick</td>
<td>i</td>
<td></td>
<td>st</td>
<td></td>
</tr>
<tr>
<td>10. shine</td>
<td>sh</td>
<td></td>
<td>i-e</td>
<td></td>
</tr>
<tr>
<td>11. dream</td>
<td>dr</td>
<td>ea</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. blade</td>
<td>bl</td>
<td>a-e</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13. coach</td>
<td>ch</td>
<td></td>
<td></td>
<td></td>
</tr>
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<td>fr</td>
<td>igh</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15. chewed</td>
<td>ch</td>
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<td>cr</td>
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<td>aw</td>
<td></td>
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<td>17. wishes</td>
<td>sh</td>
<td></td>
<td></td>
<td>-es</td>
</tr>
<tr>
<td>18. thorn</td>
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<td>ou</td>
<td>-ed</td>
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<td>20. spoil</td>
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<td></td>
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</tr>
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<td>21. growl</td>
<td>g</td>
<td></td>
<td>ow</td>
<td></td>
</tr>
<tr>
<td>22. third</td>
<td>th</td>
<td></td>
<td>ir</td>
<td></td>
</tr>
<tr>
<td>23. camped</td>
<td></td>
<td></td>
<td></td>
<td>-ed</td>
</tr>
<tr>
<td>24. tries</td>
<td>tr</td>
<td></td>
<td>-ies</td>
<td></td>
</tr>
<tr>
<td>25. clapping</td>
<td></td>
<td></td>
<td>-pling</td>
<td></td>
</tr>
<tr>
<td>26. riding</td>
<td></td>
<td></td>
<td>-ding</td>
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</tr>
</tbody>
</table>

**Totals**: 7 / 7 / 7 / 7 / 7 / 7 / 7 / 7 / 7 / 56 / 26
APPENDIX D

Multiple Regression: Histograms Showing Normality of Distribution

Phoneme Segmentation Fluency (PSF)
Digit Span Forward (DSF)
Digit Span Backward (DSB)
Primary Spelling Inventory (PSI)
DSB After Transformation (Sqrt.DSB)
PSI After Transformation (Sqrt.PSI)
Phoneme Segmentation Fluency (PSF)

Digit Span Forward (DSF)

Frequency

Phoneme Segmentation Fluency (PSF) Score

Digit Span Forward (DSF) Score
DSB After Transformation (Sqrt.DSB)

PSI After Transformation (Sqrt.PSI)
APPENDIX E

Multiple Regression: Residual Plots to Check for Linear Relationships

Standardized Residual Against PSF
Standardized Residual Against DSF
Standardized Residual Against Sqrt.DSB
Standardized Residual Against Sqrt.DSB
APPENDIX F

Multiple Regression: Histogram to Check for Normally Distributed Errors
Multiple Regression: Histogram to Check for Normally Distributed Errors
APPENDIX G

Multiple Regression: Outlier Plots

Covariance Ratio
Cook's Distance
Centered Leverage Value
Mahalanobis Distance
Standardized DFBeta PSF
Standardized DFBeta DSF
Standardized DFBeta Sqrt.DSB
Predicted Sqrt.PSI
Comparison of Outlier Measures
Centered Leverage Value

Mahalanobis Distance
### Comparison of Outlier Measures

<table>
<thead>
<tr>
<th>Outlier Test</th>
<th>Case Numbers of Outliers and Additional Times Identified</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>17 86 64 20 21 19 49 12 34 99 66 41 81 32 100</td>
</tr>
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<td>Covariance Ratio</td>
<td>-   -   -   -   -   -   -   -   -   -   -   -   -   -   -</td>
</tr>
<tr>
<td>Cook’s distance</td>
<td>-   -   -   -   -   -   -   -   -   -   -   -   -   -   -</td>
</tr>
<tr>
<td>Leverage distance</td>
<td>-   -   -   -   -   -   -   -   -   -   -   -   -   -   -</td>
</tr>
<tr>
<td>Mahalanobis distance</td>
<td>-   -   -   -   -   -   -   -   -   -   -   -   -   -   -</td>
</tr>
<tr>
<td>DFBeta PSF</td>
<td>-   -   -   -   -   -   -   -   -   -   -   -   -   -   -</td>
</tr>
<tr>
<td>DFBeta DSF</td>
<td>-   -   -   -   -   -   -   -   -   -   -   -   -   -   -</td>
</tr>
<tr>
<td>DFBeta</td>
<td>-   -   -   -   -   -   -   -   -   -   -   -   -   -   -</td>
</tr>
<tr>
<td>DSB</td>
<td>-   -   -   -   -   -   -   -   -   -   -   -   -   -   -</td>
</tr>
<tr>
<td>Predicted</td>
<td>-   -   -   -   -   -   -   -   -   -   -   -   -   -   -</td>
</tr>
<tr>
<td>Sqrt.PSI</td>
<td>-   -   -   -   -   -   -   -   -   -   -   -   -   -   -</td>
</tr>
<tr>
<td>Additional Times</td>
<td>3   3   3   2   4   4   3   4   3   3   2   1   0   2   2</td>
</tr>
<tr>
<td>Identified</td>
<td></td>
</tr>
</tbody>
</table>

Notes. Case numbers of CVR outliers (in descending order of magnitude) and case numbers of CVR outliers which were also outliers on other tests in comparison to the majority of data points.