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

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**Abstract:** 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 to the middle of grade 2. 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 improve the prediction of spelling achievement by including other measures linked to literacy, such as letter-sound knowledge.

**Keywords:** Phonemic Awareness, Verbal Short-Term Memory, Working Memory, Spelling Achievement, Grade 1, Thailand.

## Introduction
Spelling is an especially challenging task for young students on the path to literacy (Gurney-Read, 2015). Unfortunately, English is a complicated language, particularly as there are different spellings of the same sounds and many foreign words that have

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been integrated into the language over the years. There are a wide variety of approaches to spelling in schools including the use of phonics, spelling programs, and lists derived from sources such as reading programs. However, there are divided opinions about teaching spelling, with some saying that the rote memorization involved is not useful, while others point to falling literacy standards to promote its importance (Gentry, 2011; Schlagal & Trathen, 1998). Spelling achievement (SA) depends on learning knowledge about spelling and being able to apply it to unfamiliar words (Kingsley, 2012).

Phonemic awareness (PA) is a student's ability to distinguish and manipulate the shortest units of sound of which spoken words are comprised, and is required in order to manipulate sounds and spell (Ebert, 2009; Good & Kaminski, 2002).

Memory is important for many academic tasks, with limited capacity for both temporary information storage and manipulation - such as the word being spelled and knowledge of spelling. This appears to make use of (1) verbal short-term memory (VSTM) for maintaining sounds in temporary memory and learning a new language, as words that are read are subvocalized and processed in the same way as when listening; and (2) a general memory resource, working memory (WM), 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).

The main significance of the study will be to improve planning and delivery of spelling instruction in Grade 1 at Thai Christian School to take into account the strengths and weaknesses identified in each of these areas. There was a lack of research into English spelling with bilingual young learners in Thailand.
The researcher wished to know: (1) Are Grade 1 students at Thai Christian School developing useful knowledge about spelling which can be applied to unfamiliar words? (2) How important for spelling is being able to recognize the separate sounds in a word? (3) Is spelling dependent upon the capacity to hold words and sounds in memory and process information?

**Objectives**
This research had five 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.

**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.

**Conceptual Framework**
This study aimed 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. This relationship between the variables is shown in Figure 1 along with the respective instruments. It does not control for any other variables, although other factors are likely to influence spelling achievement, including intelligence, reading ability, different teachers and extra tuition, the first language or languages spoken at home, and the level of parental involvement.
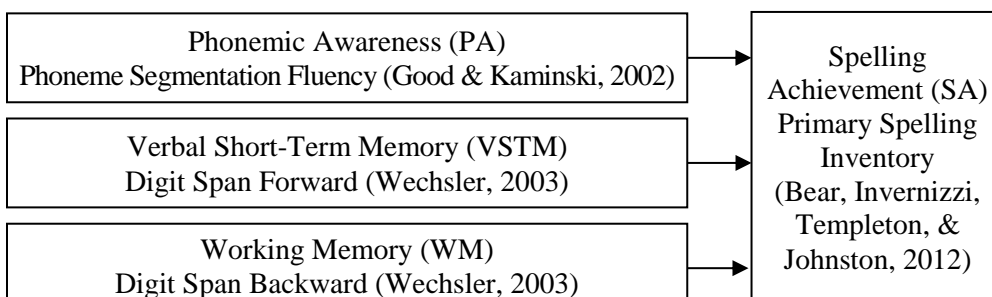
| Phonemic Awareness (PA) Phoneme Segmentation Fluency (Good & Kaminski, 2002) | → | Spelling Achievement (SA) Primary Spelling Inventory (Bear, Invernizzi, Templeton, & Johnston, 2012) |
| Verbal Short-Term Memory (VSTM) Digit Span Forward (Wechsler, 2003) | → | |
| Working Memory (WM) Digit Span Backward (Wechsler, 2003) | → | |

**Figure 1: Conceptual Framework of The Study**

**Literature Review**
This research was based on four theories: the developmental stages of spelling described by Bear et al. (2012) explain stages involved in learning to spell; Adams' (1990) hierarchy of phonemic awareness tasks classifies types of PA tasks by difficulty; and Baddeley's (2000) model of working memory describes the connection between short-term memory and working memory which links with the memory requirements of Rapp et al.'s (2002) model of the cognitive architecture of spelling. Previous studies of spelling achievement and connections with phonemic awareness and memory are examined. Details are provided about Thai Christian School and the Grade 1 spelling program.

*Developmental Stages of Spelling*
Spelling is a developmental process as students' transition from phonetic approaches only requiring knowledge of letter-sound correspondence, through to spelling within a grammatical context, which in itself requires involves levels of progression. 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).

The way students' progress towards becoming proficient spellers can be described by stages; Bear, Invernizzi, Templeton, and Johnston (2012) described five developmental stages of spelling. The 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 first three stages: (1) *emergent spelling* - students learn to use initial and final consonants; (2) *letter name-alphabetic spelling* - final consonants, short vowels, digraphs, and blends; and (3) *within word pattern spelling* - blends, common long vowels, other vowels, and inflected endings. School grade levels for these stages are shown in Figure 2

. The stage model provides a framework for assessing spelling achievement (SA) by awarding points for spelling features that correspond to successive developmental stages; alternative assessments use a scale such as 0 to 4 (Mann, Tobin, & Wilson, 1987) or 0 to 6 (Tangel & Blachman, 1995) for the completeness and sophistication of an attempt to spell.
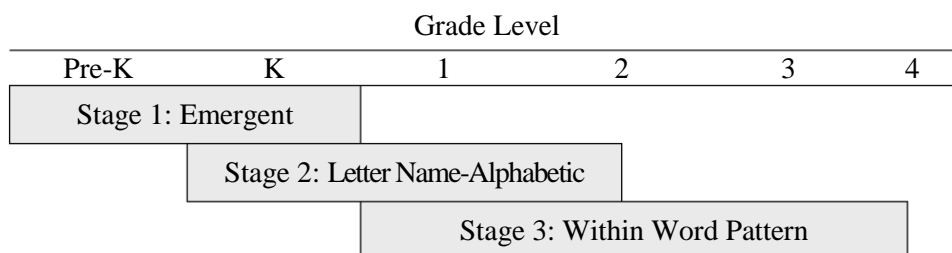


**Figure 2: Developmental Stages of Spelling; Adapted From Bear et al. (2012)**

*Hierarchy of Phonemic Awareness Tasks*

Phonemes are the short spoken sounds of a language which combine to 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). Adams (1990) described phonemic awareness (PA) as the capacity to recognize - requiring a conscious effort - that a spoken word is composed of distinct sounds smaller than a syllable (phonemes) which can be separated and altered to form new words. Adams classified PA 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 suitably challenging task for assessment of PA can be selected on the basis of this hierarchy.

Wei (2005) found that PA 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.

*Working Memory and the Phonological Loop*

Memory has remained a topic of interest due to its broad influence on learning, especially the core skills of numeracy and literacy (Bull, Espy, & Wiebe, 2008).

The working memory model proposed by Baddeley and Hitch in 1974 originally included three components, with a fourth added by Baddeley in 2000, all of which have limited capacities (Baddeley, 2000, 2007). This model has relevance as it has been supported by research specifically with children (Alloway, Gathercole, & Pickering, 2006). The components 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 associated with working memory (WM), (2) the phonological loop - a system for temporary storage of phonological information, assisted by a rehearsal mechanism which gives rise to verbal short-term memory (VSTM), (3) the visuospatial sketchpad - a system for temporary storage of visual and spatial information, 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 3. The model justifies the different types of tasks required to separately assess VSTM and WM.

Working memory in children increases with age, but the change is relative to earlier capacity, so a student with low WM will remain comparatively low. Both VSTM and WM seem to be relatively unaffected by preschool education and 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; children with lower WM may become overwhelmed by tasks.
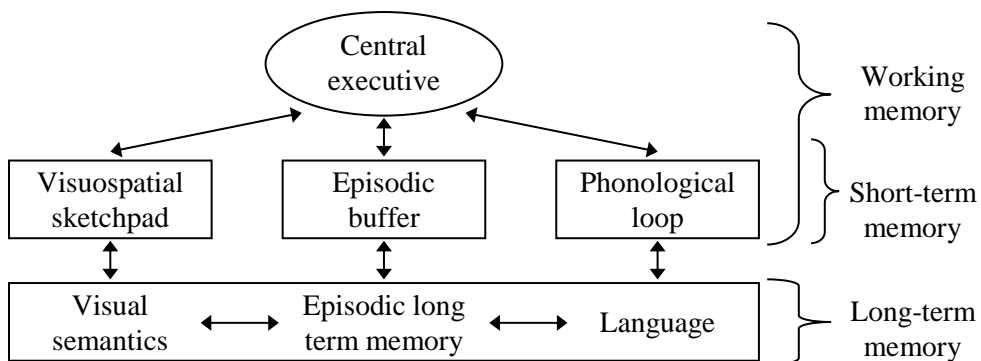


**Figure 3: Working Memory Model; Adapted From Baddeley (2000)**

A widely accepted assessment of VSTM is the recall of a sequence of digits, referred to as dit 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 - this is a Digit Span Forward (DSF) task. 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). Instead of recalling numbers in the same order, the list can be repeated from last to first, which is called Digit Span Backward (DSB). 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; Colliflower, 2013; Gathercole & Pickering, 2000).

*Cognitive Architecture of Spelling*
An insight into what types of processing demands are placed on working memory is given by Rapp, Epstein, and Tainturier's (2002) model of the cognitive architecture of spelling. It 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.

*Previous Studies of Spelling Achievement*
Phonemic awareness (PA) - or the broader term, phonological awareness, which includes longer sounds such as syllables - has been found to correlate with spelling in a number of studies, some of which also included verbal short-term memory (VSTM). The National Institute for Literacy (2008) found an average PA correlation of .40 (21 studies, 2,522 children) and .31 for VSTM (10 studies, 1,520 children). Yopp (1995) reported PA correlations in the .44 - .60 range for students between second and sixth grade, whereas Milwidsky (2009) found that, with first grade South African students, PA and VSTM did not correlate with first language students, but did in second language students. Lafrance (2007) also found English language learners had higher correlations for VSTM (.32 - .36) and PA (.49 - .61). Research by Alloway et al. (2004) and VanLoo (2003) indicated that the distinction between PA and VSTM and their relationship to spelling decrease with age as students become more proficient at spelling.

Regarding studies on working memory (WM), a study that included spelling as a measure of literacy in combination with reading found correlations of .52 for WM and .40 for VSTM at age 7 (Gathercole & Pickering, 2000). When assessing spelling alone, correlations of .36 for WM and .38 for VSTM have been reported (Alloway & Alloway, 2010). Jongejan, Verhoeven, and Siegel (2007) found WM to be a 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 their WM task requiring memory of English words in sentences.

Overall, recent research supports a link between SA and VSTM, WM, and PA, but the extent may vary according to age and English language learner status.

*Background of Spelling at Thai Christian School*
Thai Christian School was established in 1968 by the Sapan Luang Christian Church Foundation and has approximately 1,000 kindergarten to twelfth grade students. 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. In grade one to three, 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.

Although spelling is regarded as important at Thai Christian School, no commercial program has been used. 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, centered on their textbook, *English World 1* (Bowen & Hocking, 2009). Phonics lessons were taught using *English World 1* and *Phonics Fun 1 & 2* (Bunton, 2003) which covered consonants, short vowels, and some digraphs (*ch*, *sh*, *th*, *wh*, *ck*, *ll*, *ng*); blends were taught informally during day-to-day instruction. Students used 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 books: *Phonics Fun 1 & 2* or *English World 1*; 3 *common words* from the top 200 *high-frequency words in phases* (Department for Education and Skills (England), 2007); and 4 *vocabulary words* from *English World 1*.

In a typical week, spelling words are presented for students to record in a booklet and learn for homework; words are practiced with games as a class and written by copying the words onto the top of a piece of paper before folding it over and trying to recall the spelling; a test including 5 review words is given on Fridays. A marking scheme recognizing partially-correct words (Mann et al., 1987) is used, so that 0 - 4 points are available for each word.

**Method**
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 by using four assessments to measure PA, VSTM, WM, and SA respectively. After analyzing the descriptive statistics (*M* and *SD*), the data was used in a multiple regression analysis to determine if PA, VSTM, and WM could predict SA.

*Population and Sample*
This research used a population sample of all Grade 1 students in Thai Christian School at the end of the academic year (May 2015 to February 2016). There were four Grade 1 classes, two classes with 28 students in each and two with 29, for a total of 114 students. The classes were of mixed ability and mixed gender with 58% boys and 42% girls in total. 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. 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 India, Hong Kong, the UK, or the USA.

All 114 students 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.

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

*Instrument 1: Phoneme Segmentation Fluency for PA*
The Phoneme Segmentation Fluency (PSF) task (Good & Kaminski, 2002) was selected to measure the level of Phonemic Awareness (PA); it consists of 24 words that each contain 3 to 5 phonemes. It is part of the Dynamic Indicators of Basic Early Literacy Skills (DIBELS) collection of assessments widely used in the USA. It was selected due to the suitable difficulty according to the hierarchy of PA tasks described by Adams (1990), as well as availability of data on large numbers of students in kindergarten and first grade. Another benefit is the detailed scoring rubric which gives partial credit for incomplete segmentation.

Scores on the PSF task are interpreted in two ways. (1) There is a 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 to reach the benchmark level if in the 28 to 32 point range (Good & Kaminski, 2014). (2) A 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.

*Instrument 2: 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). DSF was used as a measure of verbal short-term memory (VSTM), whereas DSB was used for working memory (WM). It was standardized on 2,200 children (Flanagan & Kaufman, 2004) and the validity of DSF and DSB tasks as measures of VSTM and WM respectively with children has been established (Alloway et al., 2006; Reynolds, 1997; St Clair-Thompson, 2010). Interpretation of a DSF or DSB score from a raw score (0 to 16 points) is done by converting to a scaled score (between 1 and 19, where 10 is equivalent to a standard deviation of 0 from the mean) based on the results of students on whom the task was standardized (Wechsler, 2003); there are corresponding percentile ranks for scaled scores (Weiss, Saklofske, Prifitera, & Holdnack, 2006) and suggested descriptors for each range (Pearson Assessment Support, 2010).

*Instrument 3: Primary Spelling Inventory for SA*

The Primary Spelling Inventory (Bear et al., 2012) is a developmental spelling assessment used for kindergarten to grade 3. It was selected to assess spelling achievement (SA) based on its use in schools, high reliability, 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 scores in terms of progress with specific spelling features.

The PSI score is the number of points for words spelled correctly added to the number of feature points. Qualitative interpretation is based on (1) the number of words spelled correctly and (2) the number of feature points missed. The number of words spelled correctly gives a score out of 26 to indicate an overall level of spelling development. Second, scores out of 7 for each spelling feature on the rubric are examined: a student who missed 1 point is ready to learn more complex spelling features; missing 2 to 3 points needs further development; missing more than 3 points needs further instruction; and a student missing all 7 points needs to study earlier features instead (Bear et al., 2012).

*Validity and Reliability*

The reported reliability statistics for these instruments are shown in Table 2 alongside the reliabilities in this research: The reliability for the PSF task was very high, .08 higher than reported (Good & Kaminski, 1996); both Digit Span tasks were very similar to the reported values (Flanagan & Kaufman, 2004), .06 lower for DSF and .04 lower for DSB; and the PSI task was .11 lower than reported (Bear et al., 2012) but still reliable.

**Table 2: Reliability Statistics for the Research Instruments**

| Instrument | Reliability | | |
|---|---|---|---|
| | Statistic | Reported | This Research |
| 1. Phoneme Segmentation Fluency (PSF) | Split-half | .88 | .96 |
| 2. Digit Span Forward (DSF) | Split-half | .83 | .77 |
| Digit Span Backward (DSB) | Split-half | .80 | .76 |
| 3. Primary Spelling Inventory (PSI) | Cronbach's alpha | .93 | .82 |

**Collection of Data**

Data collection was performed in two phases. (1) 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 researcher sat opposite the student and used a clipboard when noting responses. Each student required approximately 6 minutes in total and the researcher spent 1 to 2 hours per day for 9 days collecting data. (2) The PSI was given at the same time to each of the four classes by the four English teachers (including the researcher).

*Phoneme Segmentation Fluency (PSF)*

The researcher said 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/. 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.

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, for example, /l/ /eand/ would receive 2 points.

*Digit Span Forward and Backward (DSF and DSB)*
With the DSF task, 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. If the student was able to repeat 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. One point was scored for each correct sequence, with a maximum score of 16 points.

The procedure for the DSB task differed 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, Turner, Lipsey, & Farran, 2013).

*Primary Spelling Inventory (PSI)*
The PSI consists of 26 words, ordered in terms of increasingly more advanced spelling features, which were read aloud for students to write down the spelling. 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. According to guidance on common confusions in scoring (Bear et al., 2012), students were not penalized for writing letters in a reversed manner, such as *b* and *d*, and credit was given for correctly representing features even if letters were not in the correct order or if additional letters were added - although in the latter two cases the point for correctly spelling the word would not be given.

**Findings**
The first four findings are the levels of students' phonemic awareness (PA), verbal short-term memory (VSTM), working memory (WM), and spelling achievement (SA). The fifth finding is the predictive relationship between the variables with spelling achievement.

*Levels of PA, VSTM, WM, and SA*
The level of phonemic awareness (PA) was below the kindergarten benchmark of 33 points ($M = 24.90$, $SD = 12.47$) and well-below average (3rd percentile) compared to U.S. first grade students (Cummings et al., 2011).

The level of verbal short-term memory (VSTM) ($M = 7.72$, $SD = 1.94$) was average (0 to 0.67 *SD*s above the standardized mean).

The level of working memory (WM) ($M = 4.99$, $SD = 1.57$) was average (0 *SD*s from the standardized mean).

The level of spelling achievement (SA), from the number of words spelled correctly and feature points put students at an early to middle stage of letter name-alphabetic spelling. The feature 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 after mastering earlier stages; and common long vowels, other vowels, and inflected endings were well-beyond their stage of development (see Table 3).

**Table 3: Primary Spelling Inventory (PSI) Scores**

| PSI Score | | *M* | *S.D.* | Min. | Max. |
|---|---|---|---|---|---|
| Total / 82 points | | 25.11 | 12.20 | 0 | 58 |
| Correct Words / 26 points | | 3.77 | 2.96 | 0 | 15 |
| Feature (7 points each) | Spelling Stage Range | | | | |
| 1. Consonants: initial | Emergent (L) | 5.68 | 1.73 | 0 | 7 |
| 2. Consonants: final | Emergent (L) - Letter name-alphabetic (E) | 4.90 | 1.98 | 0 | 7 |
| 3. Short vowels | Letter name-alphabetic (E) - Letter name-alphabetic (M) | 4.64 | 1.81 | 0 | 7 |
| 4. Digraphs | Letter name-alphabetic (M) - Letter name-alphabetic (L) | 2.43 | 1.91 | 0 | 7 |
| 5. Blends | Letter name-alphabetic (L) - Within word pattern (E) | 2.25 | 2.23 | 0 | 7 |
| 6. Common long vowels | Within word pattern (E) - Within word pattern (M) | 0.46 | 1.05 | 0 | 5 |
| 7. Other vowels | Within word pattern (M) - Within word pattern (L) | 0.55 | 0.94 | 0 | 4 |
| 8. Inflected endings | Within word pattern (L) - Syllables and affixes (E) | 0.42 | 0.69 | 0 | 3 |

*Notes*. (E) = early stage, (M) = middle stage, (L) = late stage.

*Predictive Relationships*

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), a multiple regression was performed using a stepwise method for entry of variables.

Linear relationships, multicollinearity, normal distributions, homoscedasticity, normally distributed errors, and outliers were checked:

1. The DSB data was found to be moderately non-normal regarding both skewness ($z = -5.17$) and kurtosis ($z = 5.99$); a square-root transformation was chosen to improve the normality by first making a reflection 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 ($z = 2.86$).

2. A moderate lack of homoscedasticity was corrected with a square root transformation of the PSI data (Sqrt.PSI) by first adding 1 to shift values to 1 or greater.

3. No outliers were excluded; outliers were identified from their covariance ratio (CVR) values, but none were identified by other measures (Cook's distance, leverage values, Mahalanobis distances, and standardized DFBeta values).

PA, VSTM, and WM were significant predictors of SA. The model accounted for 44% of the variance in SA. Table 4 shows the results of the multiple regression analysis of PSF, DSF, and Sqrt.DSB with Sqrt.PSI.

**Table 4: Multiple Regression Analysis for Variables Predicting Spelling Achievement**

| Variable | $B$ | $SE\ B$ | $\beta$ | Sig. |
|---|---|---|---|---|
| PSF | 0.05 | 0.01 | .52*** | .000 |
| DSF | 0.14 | 0.05 | .21** | .006 |
| Sqrt.DSB | 0.66 | 0.25 | .19** | .009 |
| (Constant) | 3.83 | 0.67 | | .000 |
| $R^2$ | .44 | | | |
| $F$ | 28.52*** | | | |

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

Table 5 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) is related 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 5: Multiple Regression Correlations with Sqrt. PSI**

| Variable | Correlation | | |
|---|---|---|---|
| | Zero-order | Partial | Part |
| PSF | .59 | .56 | .50 |
| DSF | .35 | .26 | .20 |
| Sqrt.DSB | .30 | .25 | .19 |

*Further Finding: Trends in Spelling Achievement*
Following the regression, the researcher was interested in visualizing how students' actual SA related to combinations of high and low levels of PSF, VSTM, and WM. This was problematic given that the model only accounted for a moderate amount of variance, 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 4, where the boxplots show PSI scores for low, medium and high PSF levels (PSF Group) when also grouped as having (1) both low VSTM and WM, (2) low VSTM or low WM, and (3) both high VSTM and WM.
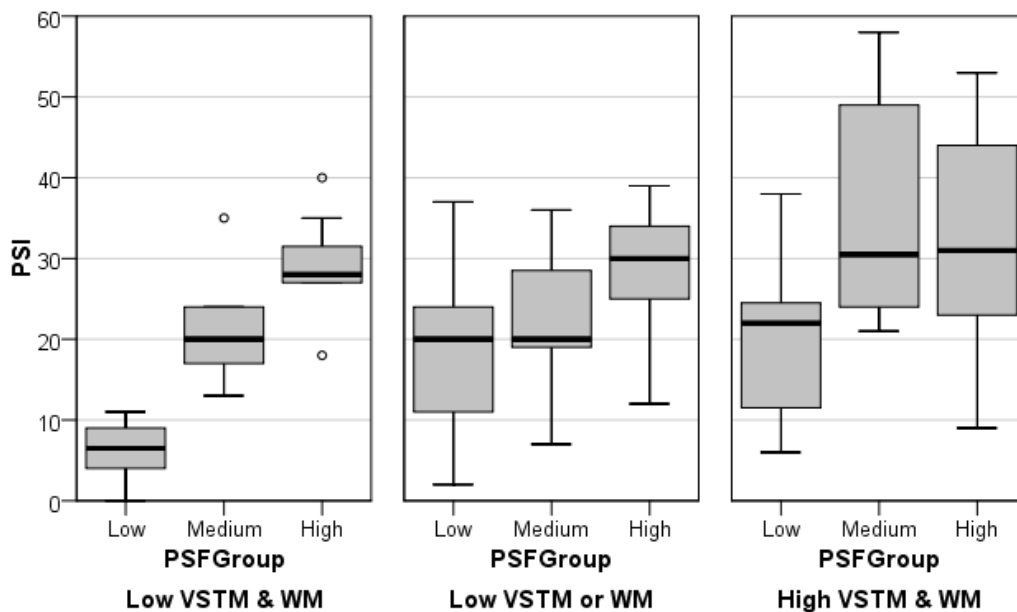


**Figure 4: Spelling Achievement Grouped by Performance on Other Variables**

## Conclusions

The level of phonemic awareness (PA) was much lower than U.S. first grade students (Cummings et al., 2011); verbal short-term memory (VSTM) was at or slightly above an average level; working memory (WM) was at an average level; and spelling achievement (SA) was within the expected range for kindergarten to the middle of grade 2.

Multiple regression showed PA, VSTM, and WM were all significant predictors of SA with positive relationships, therefore the hypothesis is accepted at the .05 significance level. The model accounted for a moderate amount of variance in SA; PA accounted for the greatest variance; VSTM and WM accounted for similar but lesser amounts.

## Discussion

*Phonemic Awareness*

Phonemic awareness (PA) was in an average range for U.S. kindergarten students, but well-below average for first grade students (Cummings et al., 2011). U.S. students

would receive PA instruction, including intervention if below the benchmark level, (Good & Kaminski, 2014) and would gain familiarity with testing. A lack of familiarity with the words in the test in comparison to native speakers may require more VSTM and WM. Although Wei (2005) found PA in Thai primary school students transferred to English, the researcher observed issues with Thai language interference, particularly final consonants, and both long and short vowel sounds seemed challenging, although this may be due to a lack of practice with producing these sounds in isolation (Adams, 1990).

*Verbal Short-Term Memory and Working Memory*
Levels of VSTM and WM were at expected average levels as literature indicated they are relatively unaffected by prior learning (Alloway & Alloway, 2010). Using English numbers in the tasks did not appear to be a problem as students were sufficiently familiar through math and English classes, but, students with weaker English may have been limited.

*Spelling Achievement*
The mean performance on each spelling feature, as shown in Table 3, was consistent with the developmental stages model (Bear et al., 2012). The number of words spelled correctly and feature point analysis indicated students were, on average, in the middle of the letter name-alphabetic spelling stage of development, but the more detailed feature point analysis indicated the range was from the early to middle part of the stage. Based on the mean feature points missed, students were near to mastering initial consonants, but needed further practice with final consonants and short vowels.

With initial consonants (feature 1), 11% of students missed more than 3 points (indicating a need for further instruction or to study earlier features), who were therefore still in the late emergent stage (see Table 3) and probably need intensive support to ensure they are able to catch up. With final consonants (feature 2) in the late emergent to early letter name-alphabetic stage, 18% missed more than 3 points. With short vowels in the early to middle letter name-alphabetic stage (feature 3), 26% missed more than 3 points. For feature 1 to 3 respectively, 69%, 46%, and 35% only missed 0-1 points (ready to move on). The researcher had expected more students to be at the point of moving on beyond feature 2 and 3; most students were within 2 points of a full score for feature 2 (72%) and feature 3 (61%), so students were nearing mastery.

Regarding later developmental features, mean scores placed students as needing further instruction on digraphs and blends (feature 4) once they mastered earlier steps; common long vowels (feature 5), other vowels (feature 6), and inflected endings (feature 7) 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 feature 4 to 7 respectively; 7% were ready to move on from feature 4 and 12% from feature 5. Although the mean score put students at the early to middle of stage 1, typical of kindergarten or first grade, a small percentage of students were spelling at a first to second grade level.

Considering only the phonics topics in the Grade 1 English curriculum at Thai Christian School (consonants, short vowels, and digraphs), students might have had

the knowledge to score 7 out of 7 on initial consonants, final consonants, short vowels, and digraphs, and spell 5 words correctly (*fan*, *pet*, *dig*, *rob*, and *gum*), giving a PSI score of 33 points. Compared with the feature points missed in these categories, the greatest need for improvement was with digraphs; short vowels were slightly more problematic than final consonants. The mean score was 2.89 words spelled correctly on those 5 specific words; this could be expected from a lack of mastery of vowels and final consonants. 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.

The impression the researcher described earlier regarding the PSF task and difficulty with final consonants is evident 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.

*Predictive 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 ratios of the standardized regression coefficients (beta weights) in Table 4 show that VSTM and WM had a similar importance in predicting SA, but PA was almost three times more important. Previous studies 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 .47; here the zero order, partial, and part correlations for PA were .50 to .59, which are at the higher end of the range, 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).

A lack of correlation between DSF and DSB ($p = .14$ and non-significant at the .05 level may support the position of previous researchers (Alloway et al., 2006; Colliflower, 2013; Gathercole & Pickering, 2000) that DSB is a WM task, rather than VSTM, in the case of young children due to high processing requirements.

Previous studies reported VSTM correlations in the range of .31 to .40, with an average of .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. In this research it was lower, .19 to .30. However, both WM correlations reported in previous research were composite literacy scores which included both spelling and reading; there could be greater demands on WM from reading than spelling, which would be true if the reading task involved more complex processing (Milwidsky, 2009). Potentially the correlation was lowered 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 (Weiss et al., 2006). Students may be under-utilizing WM if they rely more on a sub lexical approach of converting sounds to letters than considering lexical information: meaning and knowledge of spelling frequencies /patterns (Rapp et al., 2002).

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 = loy*). 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*).

Students with high SA and 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: 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 where phonics becomes less important in higher stages of spelling development; 4 students in this category mostly scored 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 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*.

From a teaching point of view, that VSTM and WM were much less important than PA is good news, as large increases in PA appear possible during 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 difficult to change as they are relatively unaffected by prior learning (Alloway & Alloway, 2010).

*Further Finding: Trends in Spelling Achievement*
Figure 4 displayed 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, which could indicate this is advantageous in spelling development. Low PA did not appear to limit SA, however low PA groups contained some of the lowest SA scores. With 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*
The PSF task was a reliable instrument, but an alternative 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 and PSF scores can reflect speed as much as accuracy, yet in this study spelling is focused on accuracy.
The model could only account for 44% of the variance in SA, so a more complete model needs to include additional predictors. Likely to be next biggest predictor is letter-sound knowledge (phonics) for written representation of sounds, but this would require great care to accept all possible correct answers (Treiman, Tincoff, Rodriguez, Mouzaki, & Francis, 1998).

Another possible inclusion in the model is reading ability as an indication of exposure to printed text, 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 spelling and reading (Invernizzi & Hayes, 2004).

A further addition could be 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 explain cases where students are weaker in VSTM or PA but have a higher SA than expected.

This research used multiple regression to investigate a linear model of predictive relationships with SA, but nonlinear models could also be explored.

## Recommendations

### Recommendations for Teachers

Students do not necessarily need a high level of phonemic awareness (PA) to spell well, but it appears to be advantageous. Students can learn and practice skills for PA specifically, not only letter-sound correspondence in phonics. This has the potential to increase the ability of students to accurately and quickly identify sounds in words. Differences between Thai and English appear to be problematic for students when trying to segment words.

Lower levels of verbal short-term memory (VSTM) and working memory (WM) are not necessarily barriers to good spelling achievement (SA), but, in combination with low PA, such students could be expected to have very low SA; they are likely to need support to improve their SA as they will probably struggle to sound out letters on their own. Conversely, students with high VSTM and WM in combination with medium to high levels of PA may have the highest SA potential.

Some students can benefit from further practice in early spelling features (final consonants and short vowels) before receiving 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. 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

A wide range of spelling achievement (SA) can exist among students in the same grade level, which suggests that differentiated levels of spelling instruction could be used, even with young non-native English speakers, as some students may need 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 there are easier PA tasks than segmentation. Beginning earlier could provide time for improvement and support the transition from emergent to letter-name alphabetic stages so that students are ready to move on to the within word pattern stage by the end of first grade. Low PA may be problematic for SA, so a minimum standard could be set to identify students in need of support.

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

*Recommendations for Future Research*
The instruments used for this research were suitable, but could be modified:

1. A PSF training session could enable students to perform nearer their full potential on the first assessment, however, accuracy rather than fluency in PA should better match with SA, which was not time-limited. Using made-up words could eliminate a possible advantage of segmenting words within the vocabularies of some student.

2. Digit span tasks could be performed in a student's native language. They could be repeated at a later date or the number of trials at each length could be increased to ensure assessment was not affected by a momentary lapse in concentration.

A more complete model of SA, may include: (1) letter-sound knowledge, (2) vocabulary size, (3) visuospatial short-term memory, (4) first language or languages spoken at home, and (5) parental involvement and/or time doing spelling homework. Alternative models could be investigated using methods such as a nonlinear multiple regression analysis.

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