

# Writing: handwriting and keyboarding

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### **Abstract**

According to the simple view of writing (Berninger, Abbott, Abbott, Graham, & Richards, 2002), the two important components of transcription in writing are handwriting and keyboarding, the third one being spelling. The purpose of this paper is to review the contribution of two writing modes—handwriting and keyboarding to writing performance. In the first section, the contribution of handwriting fluency to writing performance was explored through moderator analyses. We found that handwriting fluency contributes to writing significantly and consistently, and significantly contributes to specific writing measures (e.g., writing quality, writing fluency, substantive quality). We then explored the relationship between handwriting and keyboarding and compared their contributions to writing. Results indicated that performance on fluency of handwriting and keyboarding were significantly related, particularly on speed. Writing qualities under each mode was relatively competitive; however, keyboarding allows for faster writing. The findings from the two sections emphasized the importance of handwriting in writing development even though keyboarding is accessible.

**Keywords:** *handwriting; keyboarding; writing performance; primary education; school children;*

## **Introduction**

According to the simple view of writing (Berninger, 2000; Berninger & Amtmann, 2003; Berninger & Graham, 1998), writing subsumes four components: text generation, transcription, working memory, and executive functions. Among them, transcription is a critical support to text generation. Transcription consists of handwriting, keyboarding, which are both writing modes, and spelling. Confirmatory factor analyses have already shown that these two components have separate but correlated loadings (Abbott & Berninger, 1993; Berninger, Abbott, Thomson, & Raskind, 2001), and a direct path has been identified from handwriting to composition (Graham, Berninger, Abbott, Abbott, & Whitaker, 1997). Santangelo and Graham (2015) have suggested that instruction in handwriting could improve children's writing performance. Handwriting is a complex task of forming letters, numbers, and other characters, which requires a combination of cognitive functions, and fine and gross motor skills (Dinehart, 2015). Children's experimentation with handwriting begins around two years of age, and continues to develop through the formation of geometric shapes, horizontal and vertical lines, and crosses (Dinehart, 2015; Feder & Majnemer, 2007). There are two major components of handwriting: fluency and legibility (Graham, 1986; Graham & Miller, 1980; Graham, Berninger, Weintraub, & Schafer, 1998). Handwriting fluency refers to the rate or speed at which the letters or characters are accurately formed, while handwriting legibility refers to the accurate formation of the letters or characters.

### *The association between handwriting (fluency and legibility) and writing quality*

A myriad of studies found that handwriting proficiency is associated with writing quality. For example, handwriting fluency is positively associated with the length and quality of written compositions by beginning writers (Graham et al., 1997; Graham, Harris, & Fink, 2000). In other words, handwriting fluency can facilitate children's development of text generation and writing quality (Graham, Harris, & Chorzempa, 2002; Jones & Chirstensen, 1999). Graham, Harris, and Hebert (2011) introduced the term writer effect to honor the positive relationship between handwriting and writing quality. In reading, fluency frees up working memory space to involve in higher-level tasks, such as comprehension (LaBerge & Samuels, 1974). Similarly, the writer effect serves as a parallel relationship for writing, as handwriting fluency allows the writer to devote working memory to higher-level writing tasks, such as composition (Graham et al., 2011). McCutchen, Covill, Hoyne, and Mildes (1994) also highlight the ability of writers to dedicate attentional resources to higher-level processes in writing when handwriting becomes fluent and automatic. The presence of handwriting difficulties, including a lack of handwriting fluency, is cognitively demanding for young children so much so that they write more simply and do not participate in writing processes such as planning and revising (Graham et al., 1998; McCutchen,

1996). Furthermore, handwriting difficulties may lead to diminished self-efficacy, further resulting in children avoiding writing (Berninger, Mizokawa, & Bragg, 1991; Graham et al., 1998). Handwriting interventions have been shown to improve writing quality (Berninger et al., 1997; Jones & Christensen, 1999), and help alleviate these results. In line with the writer effect and McCutchen's (2000) explanation of fluent text generation allowing writers to overcome the limitations of short-term working memory, handwriting automaticity has been found to account for much of the variance in written expression (Jones & Christensen, 1999). As the nature of measurements of handwriting fluency is straightforward and objective, the impact of handwriting fluency, or automaticity, on writing may be considered to be trustworthy and reliable (Shaturaev, 2021b).

Measures of handwriting fluency consist mainly of two types of tasks: copying tasks and retrieval tasks. Copying tasks relate to copying a word, sentence, or paragraph of a given written text. In the copying tasks, children can have direct visual access to the targeted items. For example, Olinghouse and Graham (2009) instructed children to copy a sentence containing all of the letters as many times as possible in 1 min. Similar methods include asking children to copy as much as possible a short story in the 90s (e.g., Berninger, Cartwright, Yates, Swanson, & Abbott, 1994; Berninger et al., 1992; Swanson & Berninger, 1996). Retrieval tasks require writers to access, retrieve, and then write letters or characters with automaticity and accuracy based on prior knowledge, instead of visually accessing letters as in copying tasks, which indicates the involvement of memory along with handwriting practices. In the retrieval tasks, handwriting fluency is generally measured based on the number of correct letters or handwriting outcomes produced in a given period. In English, such retrieval tasks typically include writing all the letters following the alphabetic sequence within a given time (e.g., Christensen, 2009; Hudson, Lane, & Mercer, 2005; Wagner et al., 2011). The second aspect of handwriting is legibility, which is identified as correctly forming letters or characters. Handwriting legibility impacts others' perceptions of the writer's competence in composing (Graham et al., 1998). Neatly written papers generally receive higher grades than papers with poor penmanship, regardless of content (Santangelo & Graham, 2015). Graham et al. (2011) refer to this concept as the presentation effect. In a meta-analysis investigating the presentation effect, Graham et al. (2011) found that of the four presentation factors examined (handwriting, spelling, grammar, and word-processing printed text), handwriting legibility produced the largest weighted effect. That is, students' handwriting impacted the reader's scoring of the written composition more than any other factor. In addition,

illegible handwriting can challenge the achievement of spelling and composition (Mather & Roberts, 1995), which leads to further barriers to academic progress.

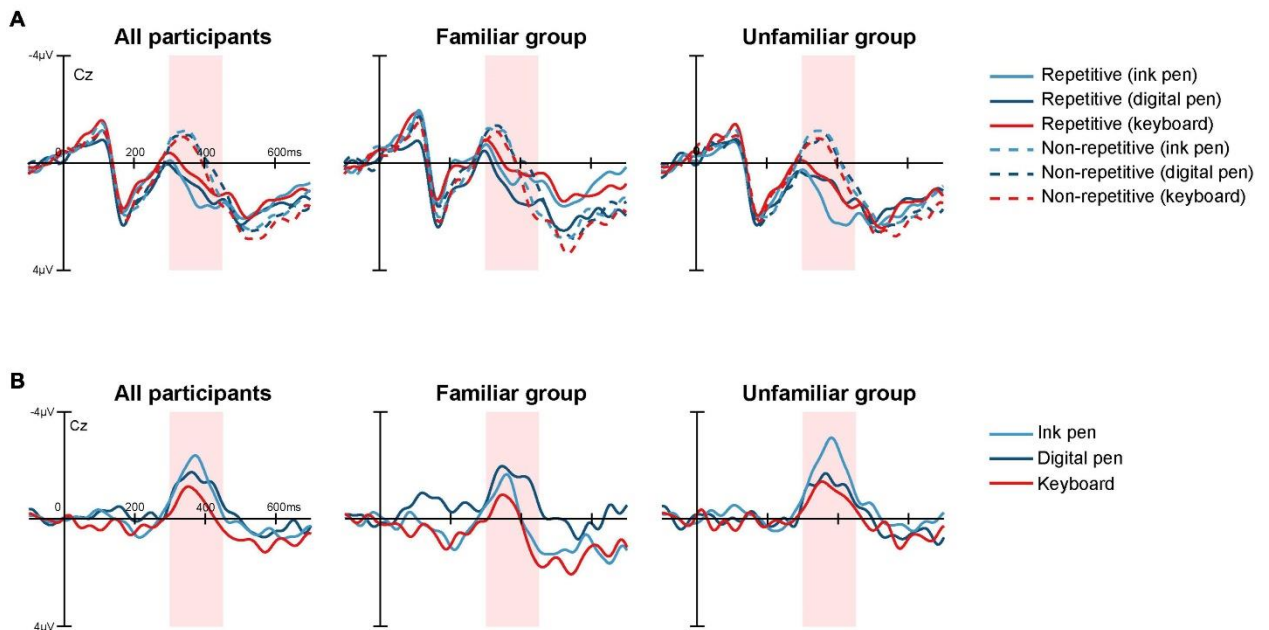


Figure 1. ERPs at Cz (midline vertex) were measured in the repetition priming paradigm.  
Source: Authoring

In Figure 1, (A) The ERPs for the target words learned using an ink pen (light blue), a digital pen (dark blue), and a keyboard (red) in the repetitive (solid line) and non-repetitive (dashed line) conditions were averaged across all participants (left), for the members of the familiar group (middle), and those of the unfamiliar group (right). (B) The ERPs for the repetitive condition were subtracted from those for the non-repetitive condition for each writing tool. The differential ERPs had a negative peak at approximately 360 ms, which represents the repetition priming effect on N400. Mean amplitudes from 300 to 450 ms (shaded in pink) were used as electroencephalographic indices for the learning effect. The amplitude was higher for words learned with the ink pen (light blue) or digital pen (dark blue) than for those learned using the keyboard (red).

To enhance students' early writing skills and minimize those obstacles, handwriting instruction with an emphasis on fluency and legibility would play an important role. For example, the extant studies found that handwriting interventions that have led to improved handwriting skills and writing quality have included instruction in legibility in addition to fluency (Graham et al., 2000; Jones & Christensen, 1999). In a study of first-grade students with and without disabilities, Graham et al. (2000) found that children receiving handwriting intervention including instruction in handwriting legibility showed both immediate and long-term improvements in written composition. Such instruction in handwriting legibility may include learning letter names, learning to form each letter of the alphabet, copying letters with numbered arrows providing step-by-step

guidelines, and reproducing letters after watching another person write the letter (Graham et al., 2000). As handwriting legibility instruction may be straightforward, the evaluation of handwriting legibility is more subjective and qualitative than the evaluation of handwriting fluency, potentially leading to inaccurate measurements (Shaturaev, 2019). Legibility may be evaluated using dichotomous coding to indicate whether the response was correct or incorrect. Graded credit may also be used to score handwriting legibility. Puranik and AlOtaiba (2012) assigned a score range as missing, incorrect, or non-recognizable letters scoring 0, recognizable but poorly formed or reversed letters scoring 0.5, and well-formed, recognizable letters a score of 1. Evaluating handwriting legibility could be embedded within the handwriting fluency evaluation simultaneously.

### *The importance of handwriting development*

Handwriting is not only an important means to communicate but also an essential life skill for all people. Children rely on handwriting heavily, because the majority of their school time could be related to performing handwriting tasks (McHale & Cermak, 1992). However, a large amount of evidence has been provided for children experiencing handwriting difficulties. The estimates of their handwriting difficulties range from 5 to 44% (e.g., Barnett, Stainthorp, Henderson, & Scheib, 2006; Graham & Weintraub, 1996; Karlsdottir & Stefansson, 2002; Sudsawad, 1999). In addition, although Hamstra-Bletz and Blöte (1993) suggested that more boys were at risk of handwriting difficulties than girls, recent results by Weintraub and Graham (2000) suggested that gender did not significantly contribute to the prediction of handwriting abilities. Therefore, poor handwriting would be a major concern for all children, as those with handwriting problems could be easily and negatively mislabeled (Sandler et al., 1992). The results of their poor handwriting include lower academic achievement and self-esteem as well as behavioral problems (Feder & Majnemer, 2007).

### *Alternative writing modes: keyboarding and handwriting*

The alternative writing mode in the simple view of writing, keyboarding, is another important component of the transcription and is positively associated with text generation. Similar to handwriting, keyboarding also carries the responsibility of producing letters promptly and accurately (Shaturaev et al., 2020). Along with the spread of technology and financial support, keyboarding has been increasingly implemented. Integrating technology into instruction has raised contradictory arguments. Some research indicated the potential to attract more children to get involved in writing (Schwabe & Göth, 2005), while others asserted that it interrupted the class discussion and student learning (Kay & Lauricella, 2011; Yamamoto, 2007). However, by using computers with word-processing programs, children could experience substantial differences in

learning attitudes, interactions, instructional strategies, and even written outcomes (Wood, 2000). Besides, research has already found a preference for keyboarding, rather than handwriting, especially among young writers (e.g., Harrington, Shermis, & Rollins, 2000; King, Rohani, Sanfilippo, & White, 2008; Lee, 2004).

*The differences and similarities between handwriting and keyboarding*

Both handwriting and keyboarding require the cognitive ability to retrieve the appropriate letters and hold them in memory (Shaturaev, 2021a). During handwriting, the writer must then access the appropriate motor functions necessary to form the letter, determine the speed with which the letter should be written, and the size in which the letter should be written. Finally, with all of this information, the writer must form the letter (Graham et al., 2000). In addition to the aforementioned retrieval skills, keyboarding requires the writer to visually recognize and select the appropriate letters on the keyboard. Keyboarders must cognitively learn the location of the keys and utilize movement patterns and keystrokes (Perminger, Weiss, & Weintraub, 2004; Sormunen, 1993).



*Figure 2. Using handwriting and typing in various ways of retrieving information*  
 Source: *Authoring*

These movement patterns and keystrokes must be memorized so that the keyboarder may begin to recognize accurate typing based on kinesthetic cues, rather than looking at the keyboard to find each letter (Perminger et al., 2004). While keyboarding requires the writer to memorize the associations between the locations of letters on a keyboard and verbal codes (Gopher & Raij, 1988; Perminger et al., 2004) along with correct positioning and timing (Perminger et al., 2004), writers executing handwriting must accurately and efficiently form each letter. The different physical requirements of handwriting and keyboarding may have different effects on writing quality and fluency while using each method of transcription. Although keyboarding seems to assert some advantages over the traditional writing mode, handwriting, Berninger (2000) proposed that it would not make handwriting obsolete. However, little has been known about whether attention to

the relationship between handwriting and writing is still necessary when the appealing alternative writing mode is available.

## **Research purposes**

Several reviews regarding handwriting and writing have been completed in recent years. Santangelo and Graham (2015) researched the significance of handwriting instruction for writing and writing development. Furthermore, Kent and Wanzek (2016) examined the association of handwriting fluency and identified a positive relationship. However, no investigation on keyboarding has been conducted. The current paper consisted of two studies to extend the previous research scope as well as fulfill this gap. In the first study, we aimed to directly examine the relationship between handwriting fluency and compositional writing measures based on the Simple View of Writing (Шатуряев Ж.Н / Бекимбетова Г.М., 2021). Instead of simply averaging the effect sizes, we relied on robust variance estimation to control the dependence of effect sizes from one particular sample. Our research questions included:

- 1. How does handwriting fluency associate with writing?*
- 2. Do any other factors constrain the concurrent relationship between handwriting fluency to writing?*

Our second study explored the relationship between handwriting and keyboarding and compared their associations with students' writing performances. A concern in this comparison was whether the possible difference was related to the writing modes or extraneous factors, like rater scoring. Accumulative research suggested no statistically significant rater bias, due to the writing and scoring modes (Harrington et al., 2000; King et al., 2008; Zhu, Shum, Tse, & Liu, 2016). In other words, the scoring on a particular composition would not be significantly different, depending on whether the composition was provided and scored by a certain rater through the written format or an online system. Since the studies that simultaneously included both handwriting and keyboarding measures often examined the same group of participants, this study aimed on synthesizing the findings from samples. Therefore, our research questions were:

- 1. How does handwriting performance associate with keyboarding?*
- 2. Do handwriting and keyboarding differ in their relationships with writing development?*

## **Method**

### *Inclusion and exclusion criteria*

Studies were searched based on the following criteria: (1) were conducted and published by 2015; (2) implemented quantitative empirical research methods; (3) included measures on both handwriting fluency and compositional writing outcomes; (4) reported sample size and bivariate

correlations between handwriting and writing; (5) were printed in English; and (6) were from either peer-reviewed journals or dissertation and thesis. Such searching constraints are used to maintain the quality of the present review as well as public accessibility, either online or in library archives. According to Garcí'a and Cain (2014), studies regarding correlation generally examined both flips of the coin: the hypothesis which supports the significance of the potential relationship among factors and that which yields opposite voices. Therefore, the search for studies would not be doubted due to concerns about publication bias. Studies were excluded if the results of the studies provided only means and standard deviations, without any correlational information. Studies with adult participants were excluded, since we focused on the school-aged population, from Kindergarten to high school level. Studies including participants with learning disabilities were retained during the preliminary search.

### **Literature search**

Studies for this meta-analysis were identified mainly through electronic searches in four databases: ERIC, PsycINFO, Web of Science, and ProQuest (including dissertations and theses global). The primary search among titles, abstracts, and keywords was conducted using Boolean combinations of terms including *handwriting fluency*, *handwriting speed/rate*, *writing*, and *composition*. We also searched the reference lists of collected documents and other relevant reviews during the coding procedure to identify additional qualified studies (Kumar et al., 2022). The initial search resulted in 93 documents, including journal articles, dissertations, and theses. Duplicated studies located from different databases were excluded. Qualitative studies and book reviews were also excluded. Utilizing the selection criteria mentioned above, a total of 16 documents were retained for further consideration. Some documents included more than one group of participants and reported their results individually. Therefore, our coding and final calculations consisted of effect sizes from 19 studies.

### *Coding procedures*

Each study was coded for study descriptors and variables which were related to effect size calculation. Study descriptors included: author information, publication year, publication type, participant feature (e.g., English language learner, students with reading/writing difficulty), number of participants, and research design (e.g., longitudinal study). The following moderator variables were coded: type of writing measures (i.e., writing quality, writing fluency, substantive quality, spelling performance, and complexity), type of handwriting measures (i.e., measurement of the letter, word, or sentence level), grade level, the genre of writing outcomes (i.e., narrative or expository text), and orthographies. We intended to examine the variation of the relationship



between handwriting and writing under different circumstances. All studies were coded by the first author and 60% of them were double-coded by the second author independently. The interrater reliability was 0.92, and disagreements were resolved through discussion.

### *Analytic procedure*

The computer program, comprehensive meta-analysis (CMA; Borenstein, Hedges, Higgins, & Rothstein, 2005) was employed for the calculation procedure. Effect sizes of each study were presented by the correlation coefficients (Pearson  $r$ ) between handwriting and writing measures. The 95% confidence interval (CI) for each effect size was calculated to test whether the specific effect size was statistically significantly different from zero. We used a recently developed statistical technique, robust variance estimation (RVE), to calculate the overall correlation and examine the impacts of moderator variables in meta-regression analyses (Hedges, Tipton, & Johnson, 2010; Tanner-Smith & Tipton, 2014). The majority of the studies included more than one measurement approach to writing quality (e.g., grammar, structure, ideas, and word choice, Kent, Wanzek, Petscher, Al Otaiba, & Kim, 2014). Some studies reported results separately based on genres of writing outcomes (e.g., Graham et al., 1997). Some studies also distinguished the correlation coefficients based on the methods of handwriting measures (e.g., word and sentence, Yan et al., 2012). The RVE technique allows the inclusion of multiple effect sizes from the same study within a given meta-analysis. Without violating the assumption of independence, this approach avoids the loss of information by dropping certain effect sizes and does not require the covariance information of effect sizes, which would be necessary for the application of other multivariate meta-analysis techniques. We used a random effect model with two assumptions: the variation between studies uses a random effect model, and the variation between studies relates to how they are drawn from the population and includes random errors. Sensitivity analyses were conducted based on different rho values (e.g.,  $q = 0.1, 0.2, \dots$ ) used for estimation in the model. In the current study, we generated the results from the rho value as 0.5 if our estimations did not show much sensitivity along with the change of  $q$ s. Lo'pez-Lo'pez, Viechtbauer, Sa'nchez-Meca, and Mari'n-Marti'nez (2010) found that the statistical power was influenced by the number of studies available, rather than the total number of effect sizes. Therefore, they suggested using a  $t$ -test to assess the statistical significance of the meta-regression coefficients.

All RVE analyses were run in SPSS 20 (SPSS, 2011), using macro downloaded from [http://peabody.vanderbilt.edu/research/pri/methods\\_resources.php](http://peabody.vanderbilt.edu/research/pri/methods_resources.php) (Tanner-Smith & Tipton, 2014). According to Tanner-Smith and Tipton (2014), RVE is applicable when the sample size is limited but produces narrower CIs and smaller  $p$  values. In other words, with a small sample size, a reported estimation, which is expected to be statistically significant at a = 0.05 level, is significant

at  $\alpha = 0.10$  level. Therefore, a lower  $\alpha$ -level should be applied to determine statistical significance (e.g.,  $\alpha = 0.01$  or  $0.001$ ) when estimating a slope and having the number of studies within the range of 10–40. Therefore, we used  $\alpha = 0.01$  to determine the significance of the estimation in the current study. Finally, we examined publication bias. Results were displayed using funnel plots and results from Egger's regression test (Egger, Davey Smith, Schneider, & Minder, 1997) and Duval and Tweedie's trim and fill analysis (Duval & Tweedie, 2000) through the analyses using the CMA program.

### *Inclusion of moderators*

As many different factors contribute to overall handwriting skill and writing quality, we coded multiple moderator variables included in this review study. In our analyses, we tested the moderation of the following factors on the relationship between handwriting and writing quality: handwriting measures, writing measures, grade level, writing genre, and orthography.

### *Handwriting measures*

The handwriting measures that were included in our analyses are measures on the letter, word, and sentence levels. That is, whether the scorers in each study scored each letter for fluency or legibility, or whether the scorers evaluated a word as a whole or even an entire sentence. Differences in the amount of handwriting that needed to be completed for each score may have varying effects on the relationship between handwriting and writing. For instance, Jones and Christensen (1999) found that orthographic-motor integration, including handwriting, accounted for more than half of the variance in written expression when assessing an entire written text in which participants were allotted 15 min to write. Connelly, Gee, and Walsh (2007) also examined handwriting based on a text produced by participants in a 15-min period in their second study. However, in their first study, they also examined handwriting speed and legibility at the letter level, assessing each letter formed in a 2-min time. The authors found that the number of correct letters produced increased with age and that students with more fluent handwriting produced better quality written texts. As these studies show the use of different handwriting measures, we included handwriting measures as a possible moderator of the relationship between handwriting and writing.

*Grade level* Due to opposing findings in previous research, it is unclear whether handwriting improves linearly with grade level, or if writers experience a period of developmental increases and plateaus (Graham et al., 1998). In a meta-analysis examining the impact of component skills on writing quality, Kent and Wanzek (2016) analyzed grade level as a possible moderator.

Whereas the authors found that grade level was not a statistically significant moderator between handwriting and writing quality, the strength of this relationship was greater for younger students (Grades K–3), emphasizing the importance of handwriting fluency for young writers.

### *Writing genre*

Two writing genres were analyzed as possible moderators of the relationship between handwriting and writing: narrative and expository. Graham et al. (1997) examined the role of handwriting concerning both compositional fluency and compositional quality among primary and intermediate children. For both primary and intermediate children, the handwriting copying task was more highly correlated with narrative composition fluency, while for composition quality, the handwriting was more highly correlated with expository quality. This study highlights the need to examine writing genres as a possible moderator. *Writing measures* Types of writing measures included writing quality, writing fluency, substantive quality, spelling performance, and complexity. Whereas writing quality may refer to the written substance of the paper including factors such as grammar, imagination, organization, and word choice, writing fluency may refer to the generation of written text (Graham et al., 2000). In addition to writing genres, Graham et al.'s (1997) study highlights the need to examine writing measures such as writing quality, writing fluency, and spelling performance as possible moderators. In addition to the finding that the correlation between handwriting and writing quality was higher for expository texts, the correlation between handwriting and writing fluency was higher for narrative texts for both primary and intermediate children, the authors also found that the correlation between handwriting and spelling was statistically significant for both primary and intermediate children on both the composition fluency and composition quality measures. These findings highlight the need to examine different writing measures as possible moderators.

### *Orthography*

We ran moderator analyses to determine whether the orthography of a study impacted the relationship between handwriting and writing. In a study examining component processes of writing skills among Turkish-speaking children in Grades 1 and 2, Babayigit and Stainthorp (2010) found that handwriting speed reliably and significantly predicted writing fluency or writing productivity ( $b = .66$ ). In a study of Dutch-speaking children, Drijbooms, Groen, and Verhoeven (2015) also found that handwriting fluency predicted text length (i.e., writing fluency;  $b = .24$ ). Whereas the basis of these findings is similar, the strength of the relationship between handwriting fluency and writing fluency may be different due to different orthographies.

## Results

### *Descriptive statistics*

We included 19 studies in this meta-analysis and calculated 59 effect sizes. Meanwhile, an additional 15 effect sizes based on the spelling performance of the compositions were identified separately, since some studies included spelling as one of the indices to evaluate children's writing. We separated the effect sizes on spelling performance because spelling is an independent component of the transcription based on the Simple View of Writing and supports text generation simultaneously. Such effect sizes were extracted from those on writing measures and analyzed separately to avoid inflation of the overall estimation. Besides, some studies also included additional particular spelling measures and reported their correlations with handwriting. However, in the current analyses, we did not include this kind of effect size for analysis. Only effect sizes of spelling performance that were derived from the composition processing were included and coded for further consideration. Table 1 shows qualitative descriptions of all the included studies, including the study ID, grade level of participants, total number of participants involved, handwriting measures, writing measures, genres, orthography, and unbiased effect size (correlation coefficient  $r$ ) between handwriting and writing measures. Table 2 presents a summary of the findings for the research questions. As shown in Table 1, the publication years ranged from 1992 to 2015. Based on information reported in the studies, we first examined whether gender could be an influential factor among the samples. Only the study by Wagner et al. (2011) did not include the gender distribution.

### **Note Taking Efficiency. Word Count**

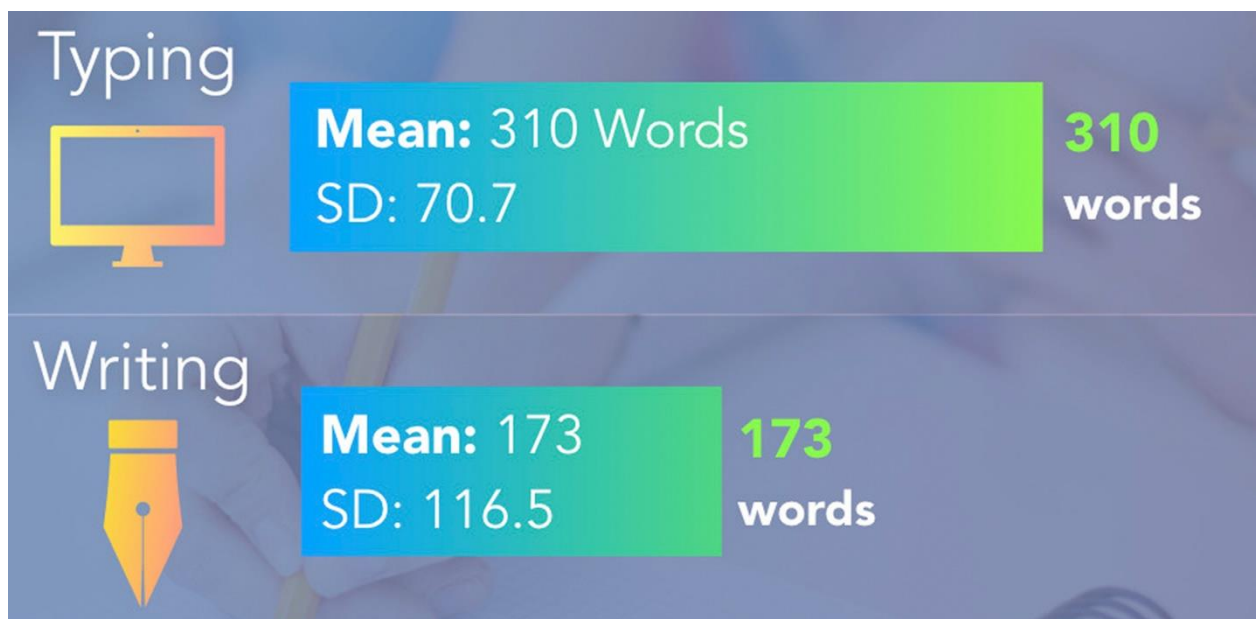


Figure 3. The Study found that typed notes tended to be longer than handwritten notes.  
Source: *Authoring*

For studies with the gender information, the percentage of girls ranged from 13.3 to 59.5% ( $M = 0.477$ ,  $SD = 0.099$ ). The study by Jalbert (2009) was an exception since the study focused on students with specific learning disabilities and recruited more males than females. After excluding this sample, a balanced design on gender was found among all the other studies (percentage of girls ranging from 41.9 to 59.5%,  $M = 0.499$ ,  $SD = 0.045$ ). We further examined the participant features. Only the participants ( $n = 15$ ) in Jalbert's study (2009) reported specific learning disabilities. Therefore, the moderator analyses did not consider the potential differences raised by either gender or special needs of participants in the studies.

*What is the relationship between handwriting fluency and writing?*

Overall, the 19 studies included 3014 participants. According to the RVE method, the effect size of the relationship between handwriting fluency and writing measures was 0.431 (95% CI [0.345, 0.517]). We used a  $t$ -test to examine the significance and found the effect size was statistically significant ( $t_{18} = 10.53$ ,  $p < .001$ ). The between-study sampling variance ( $s^2$ ) was 0.049. The Q test was significant ( $Q_e = 277.93$ ,  $df = 18$ ) and  $I^2$  indicated that 93.5% of the variation across studies was due to heterogeneity. Thus, the result suggested a positive and statistically significant association between handwriting fluency and writing measures.

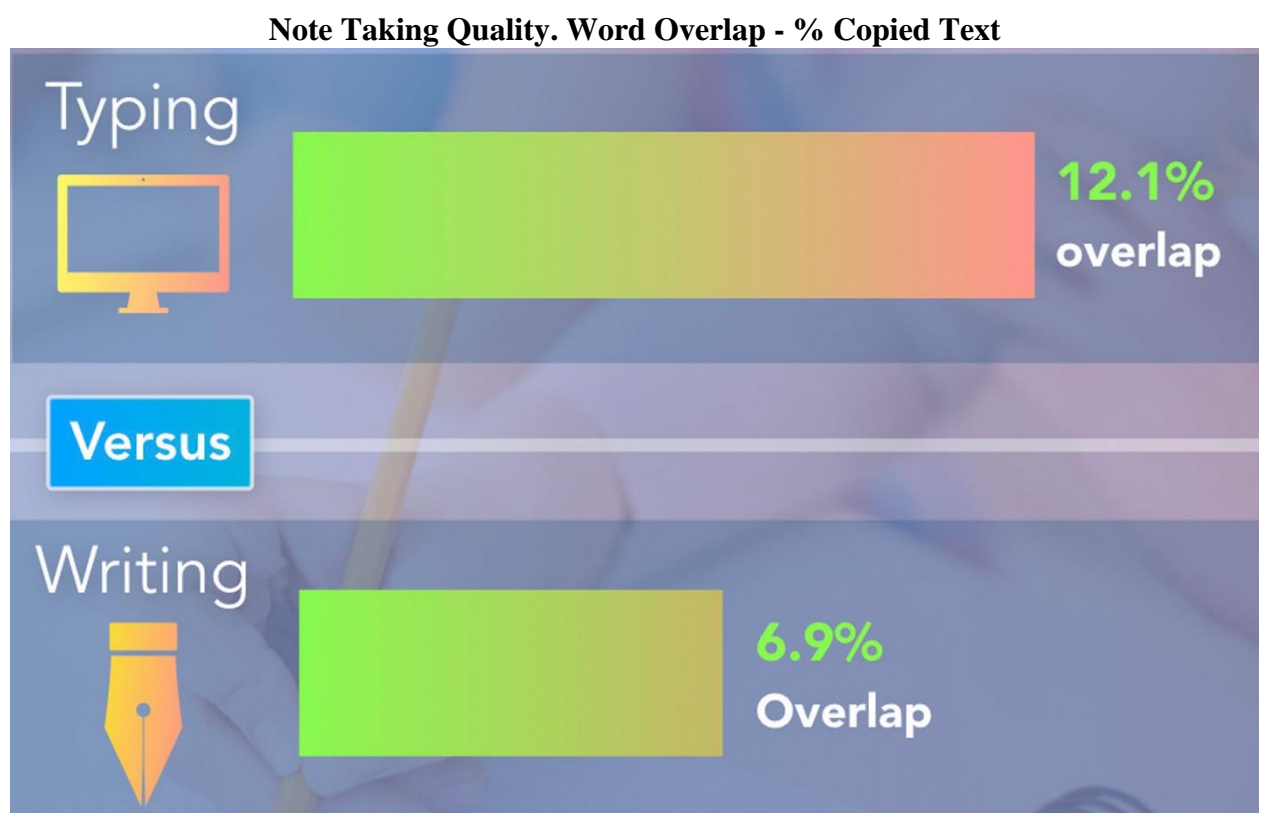
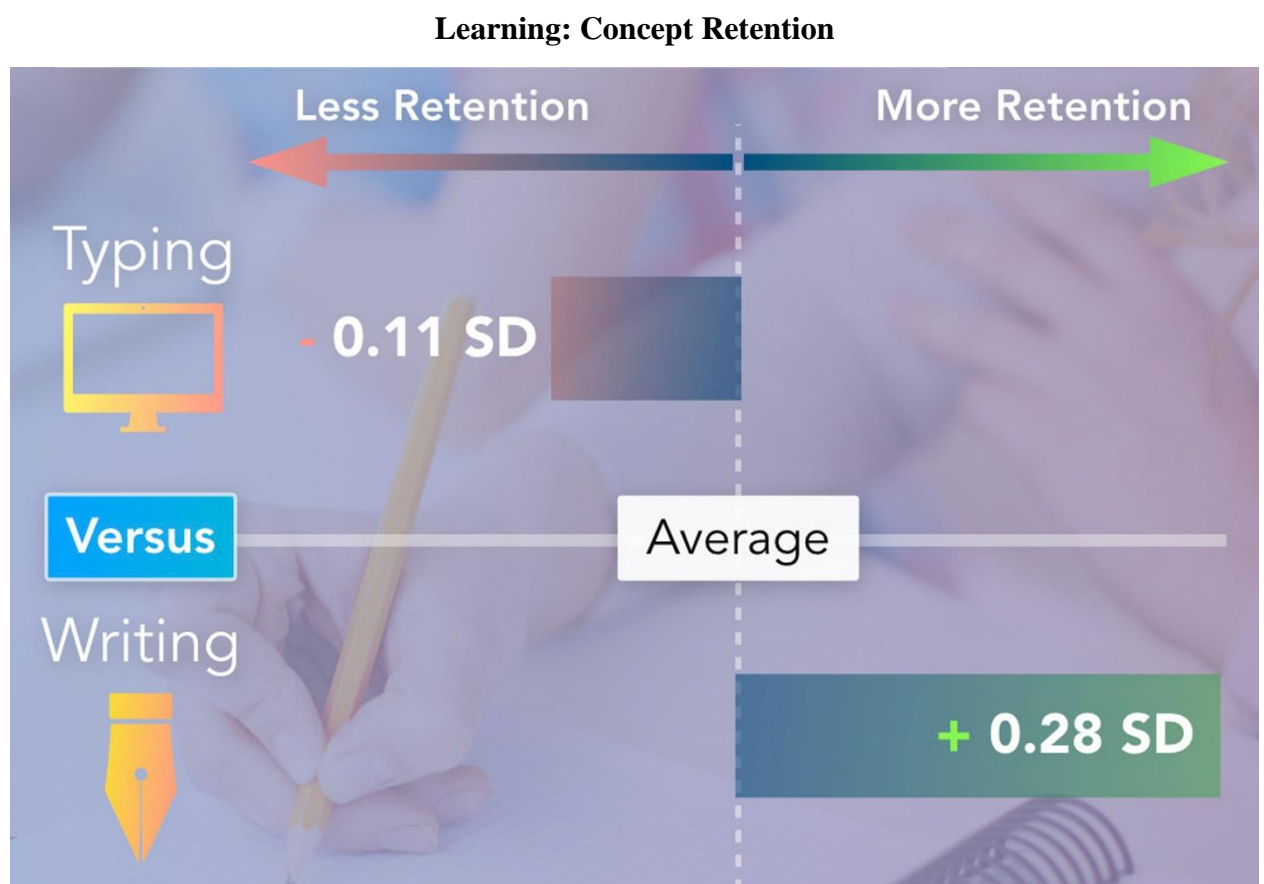


Figure 4. Students who typed notes were also significantly more likely to write things down word for word ( $p < 0.001$ )  
Source: Authoring

*Does the relationship vary across writing performances?*

As each study reported a variety of writing measures, we investigated the effect of writing measures on the relationship between handwriting fluency and writing. Hypothetically, we expected to find handwriting fluency and writing measures are consistently related. There are four categories of writing measures: writing quality ( $n = 12$ ), writing fluency ( $n = 12$ ), substantive quality ( $n = 9$ ), and complexity ( $n = 3$ ). Generally, the writing quality was presented by overall compositional scores. Writing fluency may also be referred to as writing productivity, which counted the total number of words or characters. Substantive quality was a complex construct suggested by Kim, Park, and Park (2013), which considered content measures (e.g., idea, word choice) as well as organization (e.g., number of key elements, sentence structure). Finally, complexity was measured by T-units in the words and clause density. Based on Borenstein, Gedges, Higgins, and Rothstein (2009), the power could be too low when fewer than five studies are included within one category in moderator analyses.



*Figure 5. Students assigned to take notes by hand retained more concepts than students assigned to type notes ( $p=0.02$ )*

*Source: Authoring*

Therefore, our calculation only consisted of the first three categories. Results suggested no statistical significance at  $\alpha = 0.01$  level ( $b = -0.048$ , 95% CI  $[-0.143, 0.047]$ ,  $t_{12} = -1.11$ ,  $p = 0.290$ ,  $s^2 = 0.060$ ,  $Q_e = 264.80$ ,  $df = 12$ ,  $I^2 = 95.1\%$ ). We further examined the association of handwriting fluency with each writing measure individually. Although the relationship was consistent across types of writing measures, we expected all the effect sizes should be statistically significant. Results showed the relationship of handwriting fluency with writing quality was 0.399 (95% CI  $[0.374, 0.424]$ ,  $p < 0.001$ ); with writing fluency was 0.525 (95% CI  $[0.502, 0.546]$ ,  $p < 0.001$ ); with substantive quality was 0.408 (95% CI  $[0.373, 0.442]$ ,  $p < 0.001$ ); and with complexity was 0.193 (95% CI  $[0.077, 0.303]$ ,  $p = 0.001$ ). All the relationships were significant at  $\alpha = 0.01$  level.

#### *Does the relationship vary across types of handwriting measures?*

The purpose of the third meta-regression analysis was to determine whether the type of handwriting measures influenced the relationship between handwriting and writing. We expected to see differences between copying and retrieval measures since more cognitive demands were involved for retrieval measures. Studies in our sample consisted of both copying and retrieval measures on handwriting fluency. In English, the copying measure was related to sentence production (e.g., the sentence containing all of the letters in the alphabet: “The quick brown fox jumps over the lazy dog.”). On the other hand, the copying measure was also given as writing the given words as many times as possible during a limited time. This type of measure was generally used for studies whose orthography was other than English. The words usually carried a concrete meaning (e.g., numbers and weekdays) in the specific orthography. Some studies used both approaches when measuring handwriting fluency but reported them as one construct in their correlation matrix. Overall, we found effect sizes from nine studies on retrieval tasks, ten on copying sentences, and three on repeatedly writing words, and used the first two categories for analysis. However, results indicated that retrieval tasks and copying sentences did not statistically significantly differentiate the relationship between handwriting fluency and writing as the 95% confidence interval included zero point ( $b = 0.003$ , 95% CI  $[-0.242, 0.249]$ ,  $t_{12} = 0.03$ ,  $p = 0.977$ ,  $s^2 = 0.055$ ,  $Q_e = 237.86$ ,  $df = 12$ ,  $I^2 = 94.5\%$ ). Therefore, it was concluded that the relationship between handwriting and writing was not statistically significantly influenced by which type of handwriting measures was implemented.

#### *Does the relationship vary across participants' grade levels?*

We examined the influence of participants' grade levels on the concurrent relationship and expected that a stronger relationship could be found among primary-level students. The grade level was identified by grouping participants' age or grades reported in the studies. We categorized

participants aged from Kindergarten to Grade 3 (i.e., 0 = primary level) and from Grade 4 to adolescents (i.e., 1 = intermediate or upper level) as two groups. The studies were grouped based on the experimental design (Graham et al., 1997; Medwell & Wray, 2014; Wagner et al., 2011), and the differences in the contributors to writing fluency and quality due to influences of grade levels (Abbott & Berninger, 1993). One study (i.e., Olinghouse & Graham, 2009) was excluded from this analysis since it combined second and fourth graders for correlational calculation. However, we found that participants' grade levels did not statistically significantly explain the between-study variance of the relationship between handwriting and writing at a = 0.01 level ( $b = -0.164$ , 95% CI [-0.321, -0.007],  $t_{16} = -2.21$ ,  $p = 0.042$ ,  $s^2 = 0.046$ ,  $Q_e = 254.15$ ,  $df = 16$ ,  $I^2 = 93.3\%$ ), which indicated that this relationship was consistent across grade levels.

#### *Does the relationship vary across types of writing genres?*

As the writing prompts were given in different types, we examined whether the genres of writing outcomes influenced the relationship between handwriting and writing. Most of the studies reported whether their writing prompts expected a narrative or expository composition as an outcome. However, some studies offered no hints to identify this moderator. Therefore, our coding included the genres of writing outcomes as binary (i.e., 1 = narrative, 2 = expository). Results suggested that the genres of writing outcomes did not statistically significantly explain the between-study variance of the relationship between handwriting and writing, and the 95% confidence interval included the zero point ( $b = -0.114$ , 95% CI [-0.331, 0.103],  $t_{12} = -1.14$ ,  $p = 0.275$ ,  $s^2 = 0.057$ ,  $Q_e = 227.38$ ,  $df = 12$ ,  $I^2 = 94.3\%$ ). Therefore, we concluded that the genres of writing outcomes did not significantly impact the relationship between handwriting and writing.

#### *Does the relationship vary across written orthographies?*

We conducted a meta-regression analysis to examine whether handwriting in different orthographies and writing measures influenced the relationship between handwriting and writing. We generated two groups, English and non-English (i.e., Chinese, Dutch, Korean, and Turkish). The majority of the studies (79%, 15 out of 19) were conducted in English. Results showed that the orthography did not statistically significantly explain the between-study variance of the relationship between handwriting and writing ( $b = 0.152$ , 95% CI [0.023, 0.281],  $t_{17} = 2.48$ ,  $p = 0.024$ ,  $s^2 = 0.046$ ,  $Q_e = 249.89$ ,  $df = 17$ ,  $I^2 = 92.8\%$ ). However, since the non-English group only consisted of four studies, more such research would be needed to support the consistent correlation between handwriting fluency and writing across orthographies.



### *What is the relationship between handwriting fluency and spelling in writing tasks?*

We investigated the relationship between the two transcription components. Seven studies were reporting the relationship between handwriting and spelling performance, and these spelling measures were conducted within the writing outcomes, rather than individual assessments. The hypothesis was that handwriting fluency and correct spelling should be positively associated, since reducing demands were placed on letter and sound correspondences. Three of these studies reported spelling accuracy, and the average correlation value was 0.290 (95% CI [-0.093, 0.673],  $p = 0.083$ ). The other four studies reported the number of spelling errors, and the average correlation value was -0.147 (95% CI [-0.343, 0.049],  $p = 0.097$ ). Overall, both 95% confidence intervals regarding the relationship between handwriting and spelling performance included zero points and  $t$ -tests indicated no statistical significance, which suggested no significant correlation between the two transcription components, when spelling was evaluated along with writing outcomes.

### *Publication bias*

We first explored the publication bias of the studies by the funnel plot of standard error with 95% confidence limits using CMA. There was no obvious asymmetry in the funnel plot while most studies were beyond the range of 95% confidence limits, as is shown in Fig. 1. We also examined the results of Egger's regression test and did not find evidence of publication bias or small study effect ( $b = 0.42$ ,  $SE = 2.63$ ,  $p = 0.874$ ). Furthermore, Duval and Tweedie's trim and fill analyses did not suggest any studies trimmed. Therefore, we concluded that the findings of the studies were not constrained by publication bias.

### **Discussion**

According to the presence of presentation and writer effects (Graham et al., 2011), handwriting serves as a critical factor in both the evaluation and development of writing performances. Although the contribution of handwriting instruction to writing has already been cumulatively reported, the findings from the first meta-analysis study provided further support for the beneficial relationship between handwriting and writing. Additionally, the findings from the second meta-analytic review suggested that handwriting contributed to writing as much as keyboarding did, which suggests that students should develop handwriting skills and receive explicit instruction about the technology. Results from the current studies supported the statement by Berninger (2000) and merited the benefits of handwriting as a transcription component.

### *Integration of the development of handwriting and writing*

We proposed that handwriting fluency would correlate to the writing measures significantly. The hypothesis was supported by a significant effect size of 0.423 ( $SE = 0.045$ ). We anticipated that there would be some constraints on this relationship across studies, such as grade levels, handwriting and writing measures, writing genres, and orthographies. However, the contribution of handwriting fluency to writing was relatively robust, because none of the moderator effects were identified with statistical significance. It is critical to be aware of the lower  $\alpha$ -level (i.e.,  $\alpha = .01$ ) which we applied to moderator analyses, because of the possible shrink on the estimation of confidence intervals through the RVE technique when having a limited number of studies. We further explored the contribution of handwriting fluency to each writing measure. As anticipated, handwriting fluency was identified with a significant correlation with most of the writing measures. The only exception was complexity, which emphasizes syntactic construction and manipulation. The skills of complexity relied more on executive functions, like planning and self-regulation, based on the Simple View of Writing. Besides, previous research with first- and second-language learners has suggested that complexity was further limited due to students' language proficiency levels (Larsen-Freeman, 2006; Vyatkina, 2012), although it could be improved through specific writing instruction on the text structure (Watanabe & Hall-Kenyon, 2011). Other extraneous factors, such as the text genre and the measures used, could impact the evaluation of complexity (Beers & Nagy, 2009). This might explain why we failed to find a significant relationship between handwriting fluency and complexity. The meta-analysis by Santangelo and Graham (2015) has already shown that students with handwriting instruction would perform significantly better on writing quality, writing productivity, and writing fluency compared to their peers without handwriting instruction. The practical importance of handwriting instruction is further supported through the current meta-analysis, as we found the consistency of the relationship between handwriting fluency and writing. Although the contribution of handwriting fluency varied across different writing measures, handwriting fluency was identified as a significant factor in students' performance on writing quality, writing fluency, and substantive quality. The power of our findings from the two studies on handwriting significance was compromised by the limited availability of studies. With more research considering the contributions of handwriting, its importance would be better understood.

### *Comparative influence of handwriting and keyboarding on writing*

While we notice the contribution of handwriting to writing, we are also aware of the challenges from its competitive peer, keyboarding, because both are candidates of the writing modes. If we

found the superiority of keyboarding, it is possible that keyboarding should be widely encouraged in classrooms as a substitute for handwriting practices.

We found limited studies were designed as having handwriting and keyboarding modes as treatment and control. All of the studies included in the current review had the same group of participants measured under both modes, although some studies intended to compare students' writing performances correspondingly. We found that handwriting fluency was significantly correlated with keyboarding fluency ( $r = 0.561$ , 95% CI [0.510, 0.608],  $p < .001$ ), especially on the measure of speed ( $r = 0.431$ , 95% CI [0.335, 0.519],  $p < .001$ ). In other words, students with higher handwriting fluency appeared to have higher keyboarding fluency. As Berninger and Swanson (1994) suggested that transcription consists of handwriting and spelling, the failure of accuracy measures to raise significant correlation may be due to the influence of spelling and working memory. The automatic spell check capability of keyboarding may lead to bias as well, although no study explicitly mentioned this point. When we compared the performances of handwriting and keyboarding on writing, we found that students could write faster and produce larger quantities of writing under the keyboarding mode. In other words, students produced more typed words than handwritten ones within the same period. They also had to spend more time completing their handwritten composition, although the amount of text written was not more than that under the keyboarding mode. This was not surprising, as previous research consistently suggested that most students could write faster with keyboarding (Brown, 1988). However, the advantage of keyboarding in this aspect was constrained by some limitations. The findings were generated from only two longitudinal studies, and the participants were in the same group under both modes. Although these participants had prior experience with keyboarding, their proficiency level under each mode was not explicitly identified. Furthermore, the amount of productivity was not the only major criterion of writing evaluation. The high productivity did not guarantee structured in-depth planning and then a high writing quality. For example, Mueller and Oppenheimer (2014) investigated students' learning when they took notes under different writing modes. They found that with access to keyboarding, students tended to write verbatim rather than processing information and rewording it under the handwriting condition, which could be detrimental to their learning process. Although the number of words in a typed manner could be almost three times more than those in handwritten ones, students' learning achievement was not significantly promoted with keyboarding. Similarly, when considering writing as a comprehensive practice, choices of writing modes such as either handwriting or keyboarding may not lead to a significant discrepancy to evaluate students' writing performance. We found some overlaps (i.e., correlation ranging from 0.440 to 0.526) on the 95% CIs when comparing the relationships between handwriting and keyboarding fluency on writing quality. Although the non-independent group

assignment did not allow further comparison between the two effect sizes, the evidence of overlapping indicated that handwriting and keyboarding are comparable to each other in their contribution to writing quality. Overall, despite the widespread usage of technology in classrooms, handwriting is still critical for students' writing development and should be explicitly instructed.

### **Limitations**

Admittedly, there are some limitations in our studies. We only included peer-reviewed articles and theses. Excluding other unpublished literature, such as research reports and manuscripts, could lead to insufficient representation of the relationship between handwriting, keyboarding, and writing. However, examination of publication bias suggested that the current findings were not limited due to publication bias. More studies on handwriting, keyboarding, and writing would be strongly needed for such moderator analyses. Finally, the dependence within studies on handwriting and keyboarding hindered further examination and comparison. Given the result that these two writing modes were moderately positively associated, the significance of handwriting and handwriting instruction was still highlighted, which deserved exploration in future research.

### **Conclusion**

Through the two studies related to the relationship between handwriting, keyboarding, and writing measures, we stressed the need for incorporating handwriting as an essential part of instruction in classrooms. Handwriting and keyboarding are both significantly positively associated with the development of writing, for a variety of writing measures. This further supports the simple view of writing, which emphasizes the contribution of transcription skills to text generation. Besides, handwriting did no worse than keyboarding on writing quality and significantly related to keyboarding performance, particularly on speed. In addition to identifying the significance of handwriting, the current studies also indicated additional research needs on handwriting to explore its implementation and effectiveness.

### **Conflict of interest**

The author declares that they have no conflict of interest

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## REFERENCE

1. Abbott, R. D., & Berninger, V. W. (1993). Structural equation modeling of relationships among developmental skills and writing skills in primary- and intermediate-grade writers. *Journal of Educational Psychology, 85*, 478–508. doi:10.1037/0022-0663.85.3.478.
2. \*Babayigit, S., & Stainthorp, R. (2010). Component processes of early reading, spelling, and narrative writing skills in Turkish: A longitudinal study. *Reading and Writing: An Interdisciplinary Journal, 23*, 539–568. doi:10.1007/s11145-009-9173-y.
3. Barnett, A., Stainthorp, R., Henderson, S., & Scheib, B. (2006). *Handwriting policy and practice in English primary schools*. London: Institute of Education.
4. Beers, S. F., & Nagy, W. E. (2009). Syntactic complexity as a predictor of adolescent writing quality: Which measures? Which genre? *Reading and Writing: An Interdisciplinary Journal, 22*, 185–200. doi:10.1007/s11145-007-9107-5.
5. Berninger, V. (2000). Development of language by hand and its connections with language by ear, mouth, and eye. *Topics in Language Disorders, 20*, 65–84. doi:10.1097/00011363-200020040-00007.
6. Berninger, V., Abbott, R., Abbott, S., Graham, S., & Richards, T. (2002). Writing and reading: Connections between language by hand and language by eye. *Journal of Learning Disabilities, 35*, 39–56. doi:10.1177/002221940203500104.
7. \*Berninger, V. W., Abbott, R. D., Augsburger, A., & Garcia, N. (2009). Comparison of pen and keyboard transcription modes in children with and without learning disabilities. *Learning Disability Quarterly, 32*, 123–141. doi:10.2307/27740364.
8. \*Berninger, V. W., Abbott, R. D., Jones, J., Wolf, B. J., Gould, L., Anderson-Youngstrom, M., et al. (2006). Early development of language by hand: Composing, reading, listening, and speaking The roles of handwriting and keyboarding in writing: a... 59 connections; three letter-writing modes; and fast mapping in spelling. *Developmental Neuropsychology, 29*, 61–92. doi:10.1207/s15326942dn2901\_5.
9. Berninger, V. W., Abbott, R. D., Thomson, J. B., & Raskind, W. H. (2001). Language phenotype for reading and writing disability: A family approach. *Scientific Studies of Reading, 5*, 59–106. doi:10.1207/S1532799XSSR0501\_3.
10. Berninger, V. W., & Amtmann, D. (2003). Preventing written expression disabilities through early and continuing assessment and intervention for handwriting and/or spelling problems. Research into practice. In H. L. Swanson, K. Harris, & S. Graham (Eds.), *Handbook of learning disabilities* (pp. 345–363). New York, NY: Guilford Press.
11. Berninger, V. W., Cartwright, A. C., Yates, C. M., Swanson, H. L., & Abbott, R. D. (1994). Developmental skills related to writing and reading acquisition in the intermediate grades. *Reading and Writing: An Interdisciplinary Journal, 6*, 161–196. doi:10.1007/BF01026911.
12. Berninger, V. W., & Graham, S. (1998). Language by hand: A synthesis of a decade of research on handwriting. *Handwriting Review, 12*, 11–25.
13. Berninger, V. W., Mizokawa, D. T., & Bragg, R. (1991). The theory-based diagnosis and remediation of writing disabilities. *Journal of School Psychology, 29*, 57–79. doi:10.1016/0022-4405(91)90016-K.
14. Berninger, V. W., & Swanson, H. L. (1994). Modifying Hayes and Flower's model of skilled writing to explain beginning and developing writing. In E. C. Butterfield (Ed.), *Advances in cognition and educational practice, vol. 2: Children's writing: Toward a process theory of the development of skilled writing* (pp. 57–82). Greenwich, CT: JAI Press.
15. Berninger, V., Vaughan, K., Abbott, R., Abbott, S., Brooks, A., Rogan, L., et al. (1997). Treatment of handwriting fluency problems in beginning writing: Transfer from handwriting to composition. *Journal of Educational Psychology, 89*, 652–666. doi:10.1037/0022-0663.89.4.652.
16. \*Berninger, V. W., Yates, C., Cartwright, A., Rutberg, J., Remy, E., & Abbott, R. D. (1992). Lower-level developmental skills in beginning writing. *Reading and Writing: An Interdisciplinary Journal, 4*, 257–280. doi:10.1007/BF01027151.
17. Borenstein, M., Hedges, L., Higgins, J., & Rothstein, H. (2005). *Comprehensive meta-analysis version 2 [software]*. Englewood, NJ: Biostat.
18. Borenstein, M., Hedges, L. V., Higgins, J. P. T., & Rothstein, H. R. (2009). *Introduction to meta-analysis*. Chichester: Wiley.
19. Brown, C. M. (1988). Comparison of typing and handwriting in “two-finger typists”. *Proceedings of the Human Factors Society, 32*, 381–385.
20. \*Christensen, C. A. (2004). Relationship between orthographic-motor integration and computer use for the production of creative and well-structured written text. *British Journal of Educational Psychology, 74*, 551–564. doi:10.1348/0007099042376373.
21. Christensen, C. A. (2009). The critical role handwriting plays in the ability to produce high-quality written text. In R. Beard, D. Myhill, J. Riley, & M. Nystrand (Eds.), *The SAGE handbook of writing development* (pp. 284–299). London: SAGE Publications.

23. \*Connelly, V., Gee, D., & Walsh, E. (2007). A comparison of keyboarded and handwritten compositions and the relationship with transcription speed. *British Journal of Educational Psychology*, 77, 479–492. doi:10.1348/000709906X116768.
24. Dhar, B.K., Stasi, A., Döpping, J.O. et al. Mediating Role of Strategic Flexibility Between Leadership Styles on Strategic Execution: A Study on Bangladeshi Private Enterprises. *Glob J Flex Syst Manag* (2022). <https://doi.org/10.1007/s40171-022-00310-3>
25. Dinehart, L. H. (2015). Handwriting in early childhood education: Current research and future implications. *Journal of Early Childhood Literacy*, 15, 97–118. doi:10.1177/1468798414522825.
26. \*Drijbooms, E., Groen, M. A., & Verhoeven, L. (2015). The contribution of executive functions to narrative writing in fourth grade children. *Reading and Writing: An Interdisciplinary Journal*. doi:10.1007/s11145-015-9558-z.
27. Duval, S., & Tweedie, R. (2000). A nonparametric “trim and fill” method of accounting for publication bias in meta-analysis. *Journal of the American Statistical Association*, 95, 89–98. doi:10.2307/2669529.
28. Egger, M., Davey Smith, G., Schneider, M., & Minder, C. (1997). Bias in meta-analysis detected by a simple, graphical test. *British Medical Journal*, 315, 629–634. doi:10.1136/bmj.315.7109.629.
29. Feder, K. P., & Majnemer, A. (2007). Handwriting development, competency, and intervention. *Developmental Medicine and Child Neurology*, 49, 312–317. doi:10.1111/j.1469-8749.2007.00312.x.
30. Garcí a, J. R., & Cain, K. (2014). Decoding and reading comprehension: A meta-analysis to identify which reader and assessment characteristics influence the strength of the relationship in English. *Review of Educational Research*, 84, 74–111. doi:10.3102/0034654313499616. 60 L. Feng et al.
31. Gopher, D., & Rajj, D. (1988). Typing with a two-handed chord keyboard: Will the QWERTY become obsolete? *IEEE Transactions on Systems, Man, and Cybernetics*, 18, 601–609.
32. Graham, S. (1986). A review of handwriting scales and factors that contribute to variability in handwriting scores. *Journal of School Psychology*, 24, 63–71. doi:10.1016/0022-4405(86)90043-9.
33. \*Graham, S., Berninger, V. W., Abbott, R. D., Abbott, S., & Whitaker, D. (1997). Role of mechanics in composing of elementary school students: A new methodological approach. *Journal of Educational Psychology*, 89, 170–182. doi:10.1037/0022-0663.89.1.170.
34. Graham, S., Berninger, V., Weintraub, N., & Schafer, W. (1998). Development of handwriting speed and legibility in grades 1–9. *Journal of Educational Research*, 92, 42–52. doi:10.1080/00220679809597574.
35. Graham, S., Harris, K. R., & Chorzempa, B. F. (2002). Contribution of spelling instruction to the spelling, writing, and reading of poor spellers. *Journal of Educational Psychology*, 94, 669–686. doi:10.1037/0022-0663.94.4.669.
36. Graham, S., Harris, K. R., & Fink, B. (2000). Is handwriting causally related to learning to write? Treatment of handwriting problems in beginning writers. *Journal of Educational Psychology*, 92, 620–635. doi:10.1037/0022-0663.92.4.620.
37. Graham, S., Harris, K., & Hebert, M. (2011). *Informing writing: The benefits of formative assessment*. Washington, DC: Alliance for Excellence in Education.
38. Graham, S., & Miller, L. (1980). Handwriting research and practice: A unified approach. *Focus on Exceptional Children*, 13, 1–16.
39. Graham, S., & Weintraub, N. (1996). A review of handwriting research: Progress and prospects from 1980 to 1994. *Educational Psychology Review*, 8, 7–87. doi:10.1007/BF01761831.
40. Hamstra-Bletz, L., & Blote, A. (1993). A longitudinal study on dysgraphic handwriting in primary school. *Journal of Learning Disabilities*, 26, 689–699. doi:10.1177/002221949302601007.
41. Harrington, S., Shermis, M. D., & Rollins, A. L. (2000). The influence of word processing on English placement test results. *Computers and Composition*, 17, 197–210. doi:10.1016/S8755-4615(00)00029-3.
42. Hedges, L. V., Tipton, E., & Johnson, M. C. (2010). Robust variance estimation in meta-regression with dependent effect size estimates. *Research Synthesis Methods*, 1, 39–65. doi:10.1002/jrsm.17.
43. Hudson, R. F., Lane, H. B., & Mercer, C. D. (2005). Writing prompts: The role of various priming conditions on the compositional fluency of developing writers. *Reading and Writing: An Interdisciplinary Journal*, 18, 473–495. doi:10.1007/s11145-004-7042-2.
44. \*Jalbert, R. (2009). *Essay quality of adolescents with learning disabilities: Does the medium improve the message?* Master’s Thesis, Available from ProQuest Dissertations and Theses database (MS26445).
45. \*Jones, D., & Christensen, C. A. (1999). Relationship between automaticity in handwriting and students’ ability to generate written text. *Journal of Educational Psychology*, 91, 44–49. doi:10.1037/0022-0663.91.1.44.
46. Karlsdottir, R., & Stefansson, T. (2002). Problems in developing functional handwriting (monograph supplement 1-V94). *Perceptual and Motor Skills*, 94, 623–662. doi:10.2466/PMS.94.2.623-662.
47. Kay, R., & Lauricella, S. (2011). Exploring the benefits and challenges of using laptop computers in higher education classrooms: A formative analysis. *Canadian Journal of Learning and Technology*, 37, 1–18. doi:10.21432/T2S598.
48. Kent, S. C., & Wanzek, J. (2016). The relationship between component skills and writing quality and production across developmental levels: A meta-analysis of the last 25 years. *Review of Educational Research*, 86, 570–601. doi:10.3102/0034654315619491.



50. \*Kent, S., Wanzek, J., Petscher, Y., Al Otaiba, S., & Kim, Y. S. (2014). Writing fluency and quality in kindergarten and first grade: The role of attention, reading, transcription, and oral language. *Reading and Writing: An Interdisciplinary Journal*, 27, 1163–1188. doi:10.1007/s11145-013-9480-1.
51. Kim, Y. S., Al Otaiba, S., Puranik, C., Folsom, J., Greulich, L., & Wagner, R. K. (2011). Componential skills of beginning writing: An exploratory study. *Learning and Individual Differences*, 21, 517–525. doi:10.1016/j.lindif.2011.06.004
52. \*Kim, Y. S., Park, C. H., & Park, Y. (2013). Is academic language use a separate dimension in beginning writing? Evidence from Korean. *Learning and Individual Differences*, 27, 8–15. doi:10.1016/j.lindif.2013.06.002.
53. King, F. J., Rohani, F., Sanfilippo, C., & White, N. (2008). *Effects of handwritten versus computer-written modes of communication on the quality of student essays*. Center for Advancement of Learning and Assessment (CALA Report). The roles of handwriting and keyboarding in writing: a... 61
54. LaBerge, D., & Samuels, S. J. (1974). Toward a theory of automatic information processing in reading. *Cognitive Psychology*, 6, 293–323. doi:10.1016/0010-0285(74)90015-2.
55. Larsen-Freeman, D. (2006). The emergence of complexity, fluency, and accuracy in the oral and written production of five Chinese learners of English. *Applied Linguistics*, 27, 590–619. doi:10.1093/applin/aml029.
56. Lee, H. K. (2004). A comparative study of ESL writers' performance in a paper-based and a computerdelivered writing test. *Assessing Writing*, 9, 4–26. doi:10.1016/j.asw.2004.01.001.
57. Lo'pez-Lo'pez, J. A., Viechtbauer, W., Sa'nchez-Meca, J., & Mari'n-Marti'nez, F. (2010). *Comparing the performance of alternative statistical tests for moderators in mixed-effects meta-regression models*. 5th annual meeting of the Society for Research Synthesis Methodology, Cartagena, Spain.
58. Mather, N., & Roberts, R. (1995). *Informal assessment and instruction in written language: A practitioner's guide for students with learning disabilities*. Brandon, VT: Clinical Psychology Publishing Company.
59. McCutchen, D. (1996). A capacity theory of writing: Working memory in composition. *Educational Psychology Review*, 3, 299–325. doi:10.1007/BF01464076.
60. McCutchen, D. (2000). Knowledge, processing, and working memory: Implications for a theory of writing. *Educational Psychologist*, 35, 13–23. doi:10.1207/s15326985ep3501\_3.
61. McCutchen, D., Covill, A., Hoyne, S. H., & Mildes, K. (1994). Individual differences in writing: Implications of translating fluency. *Journal of Educational Psychology*, 86, 256–266. doi:10.1207/sldrp1404\_3.
62. McHale, K., & Cermak, S. A. (1992). Fine motor activities in elementary school: Preliminary findings and provisional implications for children with fine motor problems. *American Journal of Occupational Therapy*, 46, 898–903.
63. \*Medwell, J., Strand, S., & Wray, D. (2009). The links between handwriting and composing for Y6 children. *Cambridge Journal of Education*, 39, 329–344. doi:10.1080/03057640903103728.
64. \*Medwell, J., & Wray, D. (2014). Handwriting automaticity: The search for performance thresholds. *Language and Education*, 28, 34–51. doi:10.1080/09500782.2013.763819.
65. Mueller, P. A., & Oppenheimer, D. M. (2014). The pen is mightier than the keyboard: Advantages of longhand over laptop note taking. *Psychological Science*, 25, 1159–1168. doi:10.1177/0956797614524581.
66. \*Olinghouse, N. G. (2008). Student- and instruction-level predictors of narrative writing in third-grade students. *Reading and Writing: An Interdisciplinary Journal*, 21, 3–26. doi:10.1007/s11145-007-9062-1.
67. \*Olinghouse, N. G., & Graham, S. (2009). The relationship between the discourse knowledge and the writing performance of elementary-grade students. *Journal of Educational Psychology*, 101, 37–50. doi:10.1037/a0013462.
68. \*Perminger, F., Weiss, P. L., & Weintraub, N. (2004). Predicting occupational performance: Handwriting versus keyboarding. *The American Journal of Occupational Therapy*, 58, 193–201. doi:10.5014/ajot.58.2.193.
69. Puranik, C. S., & AlOtaiba, S. (2012). Examining the contribution of handwriting and spelling to written expression in kindergarten children. *Reading and Writing: An Interdisciplinary Journal*, 25, 1523–1546. doi:10.1007/s11145-011-9331-x.
70. \*Roger, J., & Case-Smith, J. (2002). Relationships between handwriting and keyboarding performance of sixth-grade students. *The American Journal of Occupational Therapy*, 56, 34–39. doi:10.5014/ajot.56.1.34.
71. Sandler, A. D., Watson, T. E., Footo, M., Levine, M. D., Coleman, W. L., & Hooper, S. R. (1992). Neurodevelopmental study of writing disorders in middle childhood. *Journal of Developmental and Behavioral Pediatrics*, 13, 17–23.
72. Santangelo, T., & Graham, S. (2015). A comprehensive meta-analysis of handwriting instruction. *Educational Psychology Review*, 27, 1–41. doi:10.1007/s10648-015-9335-1.
73. Schwabe, G., & Go'th, C. (2005). Mobile learning with a mobile game: Design and motivational effects. *Journal of Computer Assisted learning*, 21, 204–216. doi:10.1111/j.1365-2729.2005.00128.x.
74. Shaturaev, J. (2022). THE LINKS BETWEEN THE AUTONOMY GAP IN SCHOOLS, PRINCIPAL LEADERSHIP, TEACHER JOB SATISFACTION, AND ORGANIZATIONAL COMMITMENT. *Архив научных исследований*, 2(1).
75. Shaturaev, J. N., & Bekimbetova, G. M. MODERN DIGITAL STRATEGIES-INCREASING THE DEVELOPMENT OF NATIONAL EFFECTIVE INNOVATIVE ENTERPRISES IN UZBEKISTAN.

76. Shaturaev, J. (2022). THE LINKS BETWEEN THE AUTONOMY GAP IN SCHOOLS, PRINCIPAL LEADERSHIP, TEACHER JOB SATISFACTION, AND ORGANIZATIONAL COMMITMENT. *Архив научных исследований*, 2(1). извлечено от <http://journal.tsue.uz/index.php/archive/article/view/2146>
77. Shaturaev, J. (2021). Financing and Management of Islamic (Madrasah) Education in Indonesia. *Zeszyty Naukowe Politechniki Częstochowskiej Zarządzanie*, 42(1), 57-65.
78. Shaturaev, J. (2019). The importance of handwriting in education. *International Journal of Advanced Research*, 7(12), 947-954.
79. Shaturaev, J., Iroda, J., Gulnoza, I., & Madina, R. (2020). Exploration Effects of Handwriting on Children'S Writing Progress. *International Journal of Advanced Research*, 8(9), 369-376.
80. Shaturaev, J. (2021). A Comparative Analysis of Public Education System of Indonesia and Uzbekistan. *Bioscience Biotechnology Research Communications*, 14(5), 89-92.
81. Shaturaev, J. (2021). 2045: Path to nation's golden age (Indonesia Policies and Management of Education). *Science and Education*, 2(12), 866-875.
82. Шатураев, Ж. Н., & Бекимбетова, Г. М. (2021). THE MAIN INDICATOR OF EFFICIENCY OF INVESTMENT PROJECTS-CALCULATION OF NET CURRENT VALUE. *The Scientific Heritage*, 3(77), 14-21.
83. Shaturaev, J., & Bekimbetova, G. (2021). THE DIFFERENCE BETWEEN EDUCATIONAL MANAGEMENT AND EDUCATIONAL LEADERSHIP AND THE IMPORTANCE OF EDUCATIONAL RESPONSIBILITY. *InterConf*.
84. Shaturaev, J., & Bekimbetova, G. (2021). Transformation of business efficiency with the lean management. *Deutsche Internationale Zeitschrift für zeitgenössische Wissenschaft*, (22), 71-73.
85. Shaturaev, J. (2022). Bad Management Hypotheses Are Demolishing Management Practices. *Архив научных исследований*, 2(1).
86. Shaturaev, J. (2022). FINANCING PUBLIC EDUCATION IN INDONESIA. *Архив научных исследований*, 2(1).
87. Shaturaev, J. (2022). Economies and Management as A Result of The Fourth Industrial Revolution: An Education Perspective. *Indonesian Journal of Educational Research and Technology*, 3(1), 51-58.
88. Бекимбетова, Г. М., & Шатураев, Ж. Н. (2021). Основной показатель эффективности инвестиционных проектов расчет чистой текущей стоимости. *The Scientific Heritage*, (77-3), 14-21.
89. Shaturaev, J. (2022). EQUITY ISSUES IN LOCAL RESOURCING OF EDUCATION: COMMUNITY FINANCING OF PRIMARY SCHOOLS. *Архив научных исследований*, 2(1).
90. Dhar, B. K., Stasi, A., Döpping, J. O., Gazi, M. A. I., Shaturaev, J., & Sarkar, S. M. (2022). Mediating Role of Strategic Flexibility Between Leadership Styles on Strategic Execution: A Study on Bangladeshi Private Enterprises. *Global Journal of Flexible Systems Management*, 1-12.
91. Dhar, B. K., Stasi, A., Döpping, J. O., Gazi, M. A. I., Shaturaev, J., & Sarkar, S. M. Mediating Role of Strategic Flexibility Between Leadership Styles on Strategic Execution: A Study on Bangladeshi Private Enterprises.
92. Shaturaev, J. (2022). THE LINKS BETWEEN THE AUTONOMY GAP IN SCHOOLS, PRINCIPAL LEADERSHIP, TEACHER JOB SATISFACTION, AND ORGANIZATIONAL COMMITMENT. *Архив научных исследований*, 2(1).
93. Shaturaev, J. (2022). THE LINKS BETWEEN THE AUTONOMY GAP IN SCHOOLS, PRINCIPAL LEADERSHIP, TEACHER JOB SATISFACTION, AND ORGANIZATIONAL COMMITMENT. *Архив научных исследований*, 2(1).
94. Shaturaev, J. N., & Bekimbetova, G. M. MODERN DIGITAL STRATEGIES-INCREASING THE DEVELOPMENT OF NATIONAL EFFECTIVE INNOVATIVE ENTERPRISES IN UZBEKISTAN.
95. Sormunen, C. (1993). Learning style: An analysis of factors affecting keyboarding achievement of elementary school students. *The Delta Pi Epsilon Journal*, 35, 26–38. SPSS, IBM. (2011). *IBM SPSS statistics base 20 [software]*. Chicago, IL: SPSS Inc.
96. Sudsawad, P. (1999). *Teacher referrals of poor handwriting students*. Unpublished raw data.
97. Swanson, H. L., & Berninger, V. W. (1996). Individual differences in children's working memory and writing skill. *Journal of Experimental Child Psychology*, 63, 358–385. doi:10.1006/jecp.1996.0054. 62 L. Feng et al.
98. Tanner-Smith, E. E., & Tipton, E. (2014). Robust variance estimation with dependent effect sizes: Practical considerations including a software tutorial in Stata and SPSS. *Research Synthesis Methods*, 5, 13–30. doi:10.1002/jrsm.1091.
99. Vyatkina, N. (2012). The development of second language writing complexity in groups and individuals:
100. A longitudinal learner corpus study. *The Modern Language Journal*, 96, 576–598. doi:10.1111/j.1540-4781.2012.01401.x.



101. \*Wagner, R. K., Puranik, C. S., Foorman, B., Foster, E., Wilson, L. G., Tschinkel, E., et al. (2011). Modeling the development of written language. *Reading and Writing: An Interdisciplinary Journal*, 24, 203–220. doi:10.1007/s11145-010-9266-7.
102. Watanabe, L. M., & Hall-Kenyon, K. M. (2011). Improving young children's writing: The influence of story structure on kindergartners' writing complexity. *Literacy Research and Instruction*, 50, 272–293. doi:10.1080/19388071.2010.514035.
103. \*Weintraub, N., Gilmour-Grill, N., & Weiss, P. L. (2010). Relationship between handwriting and keyboarding performance among fast and slow adult keyboarders. *The American Journal of Occupational Therapy*, 64, 123–132. doi:10.5014/ajot.64.1.123.
104. Weintraub, N., & Graham, S. (2000). The contribution of gender, orthographic, finger function, and visual-motor processes to the prediction of handwriting status. *OTJR: Occupation, Participation and Health*, 20, 121–140. doi:10.1177/153944920002000203.
105. Wood, J. M. (2000). *A marriage waiting to happen: Computers and process writing*. Boston, MA: Education Development Center. Retrieved from [http://www-tc.pbs.org/teacherline/courses/rdla215/docs/wood\\_marriagewaiting.pdf](http://www-tc.pbs.org/teacherline/courses/rdla215/docs/wood_marriagewaiting.pdf).
106. Yamamoto, K. (2007). Banning laptops in the classroom: Is it worth the hassle? *Journal of Legal Education*, 57, 477–520.
107. \*Yan, C., McBride-Chang, C., Wagner, R. K., Zhang, J., Wong, A., & Shu, H. (2012). Writing quality in Chinese children: Speed and fluency matter. *Reading and Writing: An Interdisciplinary Journal*, 25, 1499–1521. doi:10.1007/s11145-011-9330-y.
108. Zhu, Y., Mark Shum, S. K., Brian Tse, S. K., & Liu, J. J. (2016). Word-processor or pencil-and-paper? A comparison of students' writing in Chinese as a foreign language. *Computer Assisted Language Learning*, 29, 596–617. doi:10.1080/09588221.2014.1000932.