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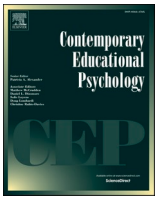

The keys of keyboard-based writing: Student and classroom-level predictors of keyboard-based writing in early primary

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ABSTRACT

In today's fast-paced digital world, keyboard-based writing has become a key component of daily communication, with students engaging in keyboarding early in their school trajectories. Nonetheless, there's a lack of systematic studies investigating individual-level factors impacting keyboard-based writing and relationships with the writing instruction typically provided in primary school settings. Using multilevel modelling the current study examined student-level predictors of keyboard-based writing quality and fluency in Year 2 Australian children (N = 544), including keyboarding automaticity, spelling, reading skills, executive functioning, writing attitudes, gender; and classroom-level (N = 47) variables predicting keyboard-based writing, such as teachers' preparation and instructional practices for writing. Results revealed that keyboarding automaticity, spelling, word reading, general attitudes toward writing, and gender were uniquely related to compositional quality. Keyboarding automaticity, word reading, and gender were also uniquely related to compositional fluency. Results also showed that female students outperformed their male peers in keyboarding automaticity, compositional quality and fluency, but also on attitudes toward writing and reading comprehension. For classroom-level factors, findings showed time teaching keyboarding positively related to compositional fluency and time teaching handwriting negatively related to compositional quality and fluency. Interactions were also found between gender and time teaching keyboarding, teaching revision and planning strategies, and specific student-level factors. The novel findings from this study suggest that, to support Year 2 students' keyboard-based writing, attention must be placed on multiple components predicting students' writing performance.

1. Introduction

In today's fast-paced digital world, developing digital literacy skills, including computer-based writing skills, is a key component for academic, professional, and personal success. Traditionally, handwriting has been the main mode of learning, instruction, and assessment in schools worldwide (Bouriga & Olive, 2021). Today, however, many children's first experiences with the written language are by writing on smartphone screens and tablets (Dahlström & Boström, 2017). The digital revolution (Weigelt-Marom & Weintraub, 2018) has brought changes to teaching and learning writing, and in several educational contexts children are expected to start developing computer-based writing skills as soon as they start formal education (Poole & Preciado, 2016).

In the recent Writer(s)-within-Community (WWC) model integrating sociocultural and cognitive models of writing, Graham (2018) proposed that "writing is simultaneously shaped and constrained by context, the capabilities, and perceptions of writers and collaborators, and the interaction between the two" (p. 258). Given the digital revolution and the ongoing increase in computer use in schools, keyboarding is now seen as an essential writing mode (Weigelt-Marom & Weintraub, 2018). Hence, it is fundamental to understand student and classroom-level

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factors contributing to the development of students' keyboard-based writing and to examine these factors in early primary education to inform educational practices (Donica et al., 2018). While there is a strong body of research showcasing relationships between student-level skills (e.g., spelling and handwriting) and handwritten composition (Kent & Wanzek, 2016) there is far less evidence for keyboard-based writing and instructional influences mediating potential relationships. To address this gap, the present study adopted the theoretical underpinnings of the WWC model (Graham, 2018) as its underlying conceptual framework to examine multilevel predictors of keyboard-based writing of children in Year 2, including child-level predictors such as keyboarding automaticity, spelling, reading skills, writing attitudes, and executive functioning, and classroom-level predictors, namely teachers' preparation and instructional practices for writing.

2. Individual-Level factors explaining writing performance

The WWC model proposes two basic organising structures shaping writing acquisition and development namely *writing community* and *writers and their collaborators*. The *writing community* structure encompasses social and cultural features of the context where writing takes place, including those assisting writing development, such as teachers. Aligned with previous cognitive models of writing (Hayes et al., 1996; Kellogg et al., 1996), the second organising structure, *writers and their collaborators,* describes individual writers' cognitive architecture in three main components that impact a final written product, namely (1) production processes, referring to mental and physical operations that writers use to compose texts; (2) long-term memory resources, namely knowledges and beliefs that individuals hold about writing and that affect writing; (3) and control mechanisms that enable writers to make decisions about multiple aspects of writing. Among the productive processes proposed in the WWC model, Graham (2018) argues that transcription skills, including keyboarding and spelling skills, play a critical role in effective writing development, especially for young writers. As per the capacity theory of writing (McCutchen, 1996), failing to automatise transcription skills constrains the writer's ability to focus on higher-order aspects of writing, including using specific strategies to plan, organise and revise texts (Dinehart, 2015; Reutzel et al., 2019). There is a strong body of empirical evidence confirming the role of transcription skills in writing. In a *meta*-analysis synthesising 25 years of research in the field, Kent and Wanzek (2016) investigated the relationship between transcription skills, including handwriting and spelling fluency, and the writing performance of K-12 students, with results showing that transcription skills accounted for approximately 25 % of the variance in writing quality. Whether via handwriting or keyboarding, it is theoretically plausible to assume that proficient automatic writing will facilitate idea generation and maximise compositional quality and fluency (Weigelt-Marom & Weintraub, 2018).

As noted in the WWC model, digital tools are now an integral part of most writing communities and changes in writing tools are likely to impact writing (Graham, 2018). Contrasting with the considerable amount of research examining associations between handwriting automaticity, spelling and writing performance in primary schooling, much less research has studied the contributions of keyboarding automaticity and spelling in explaining young students' keyboarded compositions. Non-experimental research investigating relationships between transcription skills in both writing modes found positive associations between spelling and keyboarding automaticity in early primary (Years 1–3) (Bisschop et al., 2017; Jiménez and Hernández-Cabrera, 2019). Researchers also found positive associations between keyboarding automaticity and keyboarding productivity (number of words produced) in Years 2, 4, and 6 students (Berninger et al., 2009). Findings investigating the relationships between handwriting and keyboarding automaticity in the primary years (Connelly et al., 2007) also showed significant correlations between keyboarding automaticity and the compositional quality via keyboard of primary students (Years 5–6). Overall findings make the case that keyboard-based text composing can be particularly challenging for children in the first phases of keyboarding acquisition since they rely heavily on visual feedback when searching for the right keys to press, as opposed to later stages of keyboarding acquisition, when writers rely primarily on kinaesthetic feedback to compose texts (Preminger et al., 2004). Hence, the current study aimed at examining the contributions of keyboarding automaticity and spelling in predicting young writers' keyboard-based text composing.

Motivational factors have been found to influence writing performance throughout schooling (Pajares, 2003; Troia et al., 2022). Incorporated in the WWC model as a long-term memory resource impacting writing, motivational factors, including attitudes toward writing, are said to play a critical role in writing since they may lead to positive or negative responses to a given writing task, impact subsequent actions that the writers take to complete it, and influence interactions between writers, teachers, and other students (Graham, 2018). Contemporary research on motivation in writing describes attitudes as an affective motivational state (Ekholm et al., 2018), so students may differ in their attitudes towards composing handwritten and keyboarded texts. Systematic reviews examining motivational factors in writing offer support to the contention that writing attitudes are an important predictor of primary students' writing performance (Camacho et al., 2021; Ekholm et al., 2018). For example, Ekholm and colleagues (2018) examined research published between 1990 and 2017 investigating writing attitudes and found that, in most studies reviewed, writing attitudes positively predicted the writing performance of primary students across Years 1–6, including compositional quality and fluency (ES ranged from 0.5 to 0.9). However, the authors also reported conflicting findings in the limited research examining relationships between writing attitudes and writing achievement in early education. Namely, from the four studies focused on early primary education (Years 1–3) (Graham et al., 2007; Graham et al., 2012a; Knudson, 1992; Olinghouse & Graham, 2009), only two studies found that writing attitudes influenced students' writing achievement, including writing quality and text length (Graham et al., 2007; Graham et al., 2012a). Results from Olinghouse and Graham' study (2009) using multiple regression analyses, however, showed that writing attitudes did not predict Year 2 students' writing performance. It is also worth noting that although Graham et al. (2012a) found that writing attitudes predicted Year 3 students' writing performance, writing attitudes did not predict the writing performance of Year 1 students. Ekholm et al. (2018) also reported positive associations between writing attitudes and technology use in the studies reviewed, including in upper primary education (e.g., Li et al., 2014; McGrail & Davis, 2011; Pruden et al., 2017). At the time of writing this paper, we were not able to find any study assessing beginning writers' attitudes toward writing keyboard-based texts nor any study investigating relationships between early primary students' attitudes toward composing keyboarded texts and composing performance. Aiming to address this research gap, the current study examined the contributions of writing attitudes in explaining children's keyboard-based writing.

Theoretically, the WWC model further purposes that writers hold on specific beliefs about their identities, including gender, which may impact writing performance (Graham, 2018). Empirical research does show that gender is another important student-level factor associated with primary students' writing performance. Gender differences in writing have been found in national writing proficiency assessments across countries and grades, with studies reporting a pattern of female advantage (Reilly et al., 2019; Thomas, 2020). Research findings report gender differences in primary students' writing, with female students producing higher quality text (Cordeiro et al., 2018; Malpique et al., 2017); displaying greater handwriting automaticity (Malpique et al., 2020; Skar et al., 2022) and better spelling skills (Reynolds et al., 2015); having higher self-efficacy beliefs (Graham et al, 2007; Pajares et al., 1999); and having more positive writing attitudes when compared to male students (e.g., Graham et al., 2012a; Lee, 2013). On the other hand, there is also a strong body of research pointing out gender differences in

students' attitudes toward technology and in technology use at home and at school favouring male students (Vekiri & Chronaki, 2008; Siddiq and Scherer, 2019). More commonly, research reports male students performing better than their female peers in computer-related tasks, linking this to males' higher self-efficacy and positive attitudes toward technology and technology use and using technologies more actively (Cai et al., 2017). Considering such findings favouring male students in computer-related tasks and the recurrent gender gap in paper-based writing favouring female students across grades, the present paper also aimed at expanding knowledge on the role of gender in keyboard-based writing.

Theoretical and empirical research substantiate bidirectional connections between reading and writing since writing influences reading and reading influences writing (Andersen et al., 2018; Shanahan & Lomax, 1986). As per the WWC model, reading is a core knowledge-based component of effective writing since it enables writers to locate, analyse and evaluate texts that inform specific writing tasks (Graham, 2018). Despite being independent processes, reading and writing are posited to share metaknowledge (e.g., self-monitoring and self-evaluating); domain knowledge (e.g., vocabulary, word knowledge); text attributes (e.g., mechanics, grammar, text structure); and procedural knowledge (e.g., meaning generation and analysis) (Fitzgerald & Shanahan, 2000). Research examining longitudinal relations between reading and writing found stronger reading-to-writing effects in comparison to writing-to-reading effects at the word, sentence, and text levels in Years 1 through 4 (Ahmed et al., 2014). Positive associations between word reading skills, compositional quality and compositional fluency were also found in Year 1 (Malpique et al., 2020), as well as between reading comprehension skills and written expression in Years 1 and 3 (Berninger et al., 2006). However, relationships between primary students' reading abilities and keyboard-based writing are yet to be established. To address this research gap, the current study set to investigate reading-to-writing effects in young students' keyboard-based writing.

As described in the WWC model, text composing involves the use of specific control mechanisms that potentially affect all aspects of writing since they allow writers to focus on the task at hand (Graham, 2018). Recent research has begun to address the educational implications of children's executive functioning (EF), a set of higher-order cognitive processes, including working memory, the capacity to retain and mentally manipulate information; inhibitory control, the ability to deliberately withhold dominant, automatic or prepotent responses and to resist distractions; and shifting, the ability to switch flexibly between multiple tasks, operations or mental sets, associated with intentional goal-directed behaviour (Brydges et al., 2012; Miyake et al., 2000). Despite being widely accepted, the relationship between EF and writing is grounded more on theoretical claims and less on empirical research (Limpo & Olive, 2021). Theoretically, the "not-so-simple-view" of writing (Berninger et al., 2006) offers a broad account of the role of EF in text generation, hypothesising EF to increase in importance during writing development as the complexity of writing tasks increases throughout the years. Emerging research examining associations between EF and handwriting performance (e.g., Drijbooms et al., 2015; Puranik et al., 2019; Rocha et al., 2022; Valcan et al., 2020) have confirmed a linear relation between EF and handwriting performance. The study by Drijbooms et al. (2015) investigated the contribution of EF to handwriting composition in Year 4, with results showing that EF contributed both directly and indirectly (via handwriting automaticity) to handwritten composition. Similarly, the study by Rocha et al. (2022) also demonstrated EF to predict handwritten composition, more specifically compositional quality in Year 5. However, to date, no studies have examined relations between primary students' EF and keyboard-based writing. Since it is argued that EF processes may affect all aspects of writing (Graham, 2018), the current study aimed to investigate the effects of EF in children's keyboard-based writing.

3. Classroom-level factors explaining writing performance

Consistent with sociocultural models of writing (Hull & Schultz, 2001), the WWC model proposes that writing is a socialised activity developed in writing communities, which include mentors, such as teachers, who support writers in acquiring and developing their cognitive architecture for writing (production processes, long-term memory resources, and control mechanisms) (Graham, 2018). Hence, research examining the impact of classroom-level factors in developing students' cognitive architecture for writing is needed to expand knowledge on writing acquisition and development. Findings from several *meta*-analyses on writing instruction support the role of teaching foundational skills, such as spelling, handwriting and keyboarding, and process writing skills, such as planning and revision strategies for text composing, on the promotion of effective writing development (e.g., Graham & Hebert, 2011; Graham & Santangelo, 2014; Graham et al., 2012b; Harris et al., 2023; Santangelo & Graham, 2016). Even though the evidence is less robust, providing adequate time to practice writing has been found to impact writing performance (Graham et al., 2012b). Research also shows positive associations between teachers' preparation to teach writing and students' writing performance (e.g., Gallagher et al., 2017; Wolbers et al., 2017).

In the last three decades, however, research has reported concerns about the writing instruction provided to primary students worldwide, highlighting issues in teachers' preparation to teach writing and in the nature and frequency of writing practices and instruction (Graham, 2019). Research on writing instruction has consistently reported that teachers allocate little time to teach writing in primary classrooms, both in national surveys (e.g., Bañales et al., 2020; Cutler & Graham, 2008; Veiga-Simão et al., 2016) and in observational studies (e.g., Coker et al., 2018). Researchers also found that primary teachers emphasise the teaching of spelling over the teaching of other foundational skills, such as handwriting and keyboarding, and over teaching process writing skills, such as planning and revision strategies (Cutler & Graham, 2008; Dockrell et al., 2016). In one of the few studies examining the effectiveness of writing instruction outside the context of an intervention, however, Coker et al (2018) found no positive effects of writing instruction in Year 1 students' writing performance, including writing quality and text length. In a similar non-interventional study, De Smedt et al. (2016) also found that teachers' instructional writing practices were not related to Year 5 and Year 6 students' writing performance. While both studies may raise concerns about the effectiveness of the writing instruction being provided, they stress the need to expand knowledge on class-level correlates of writing performance.

Research on teaching keyboarding skills is relatively scarce, and there's no universal agreement on the appropriate time to start formal keyboarding instruction (Donica et al., 2018; Poole & Preciado, 2016). Developed in the last century by business educators, research on typing, the antecedent of keyboarding, supports the idea that keyboarding instruction should be included in early education to prevent students from developing problem techniques that are hard to correct later, including incorrect fingering, which hinders the development of keyboarding automaticity (see Shorter, 2001 for a review). Research on keyboarding instruction shows that a minimum of 12 to 15 h of keyboarding practice is needed to support students in reaching keyboarding automaticity (Jackson & Berg, 1986) so that attention can be released for ideation and composition. However, findings from national surveys across the globe show that primary teachers report allocating little time to teaching keyboarding across grades (e.g., Dockrell, Marshall, & Wyse, 2016; Gilbert & Graham, 2010). In a time when computer-based assessment is included in many educational contexts worldwide, researchers have stressed the importance of understanding the effects of time spent enhancing keyboarding skills per grade level to inform keyboarding instruction and intervention (Donica et al., 2018).

4. The present study: Research questions and hypotheses

To foster the development of digital literacy skills, curriculum standards have been revised to encourage the inclusion of keyboard-based writing activities in several educational contexts across the globe (e.g., Australian Curriculum and Assessment Reporting Authority [ACARA], 2021; Common Core State Standards [CCSS], 2016; Wollscheid et al., 2016). In Australia, where the current study took place, keyboarding has been replacing handwriting in national exams, with children's literacy skills being assessed online, via keyboarding, in the first semester of Year 3 (ACARA, 2021). In this context, it becomes critical to expand knowledge about students' abilities to compose texts via keyboard and the instructional practices being provided to promote effective writing. Hence, the goal of this study was to investigate student-level variables and classroom-level variables predicting Year 2 students' keyboarded compositions. We addressed the following research questions: (1) Do transcription skills (i.e., keyboarding automaticity and spelling), reading skills (i.e., word reading and reading comprehension), attitudes toward writing, executive functioning (EF), and gender predict Year 2 students' keyboard-based writing (i.e., compositional quality and compositional fluency)?; (2) Do relations between student-level factors and keyboard-based writing depend on classroom-level factors (i.e., teachers' preparation and instructional practices)?

In the current study, we aimed to examine the role of specific student-level variables that have been shown to play a critical role in explaining the writing performance of beginning writers, namely letter writing automaticity and spelling (e.g., Kim et al., 2013; Malpique et al., 2020); reading skills (e.g., Berninger et al., 2010; Kent et al., 2014); attitudes toward writing (e.g., Graham et al. 2007; Graham et al., 2012a); executive functioning (e.g., Puranik et al., 2019; Valcan et al., 2020); and gender (e.g., Malpique et al. 2017, 2020; Skar et al., 2022). We further aimed to examine the role of specific classroom-level factors found to account for variability in the writing performance of beginning writers, namely teachers' preparation (Malpique et al., 2020), amount of writing practice (Puranik et al., 2014) and amount of time teaching foundational and process writing skills (e.g., Graham et al., 2012b; Graham & Santangelo, 2014; Santangelo & Graham, 2016).

Regarding our first research question, we anticipated positive effects of keyboarding automaticity and spelling on students' keyboarded composition considering previous research investigating student-level factors impacting paper-based writing performance and the few studies examining keyboard-based writing performance effects previously reviewed here (e.g., Bisschop et al., 2017; Connelly et al., 2007; Kent & Wanzek, 2016). We further expected that students' attitudes toward writing would affect students' keyboard-based writing performance considering research previously reviewed in this paper (e.g., Ekholm et al., 2018). Given evidence supporting stronger reading-to-writing relations in early primary (e.g., Ahmed et al., 2014), we anticipated positive effects of reading on students' keyboarded composition, but this assumption was set with caution since relationships between reading and keyboard-based writing have not yet been established. Research has consistently reported gender differences favouring female students across motivational aspects of writing and writing outcomes, as previously reviewed here (e.g., Reilly et al., 2019; Thomas, 2020). However, a strong body of research also reports gender differences favouring male students in overall computer-based performance, self-efficacy, and attitudes toward technology (e.g., Cai et al., 2017). Hence, we anticipated gender effects on students' keyboarded composition potentially favouring males. Finally, we anticipated positive effects of EF on students' keyboarded compositions given the strong theoretical claims of possible associations between EF and writing (Graham, 2018) and emerging evidence of associations between EF and handwriting performance (Valcan et al., 2019).

Regarding our second research question, our expectations were less straightforward. On the one hand, we anticipated that teachers' perceived quality of preparation to teach writing would positively affect students' keyboarded composition since previous research has shown that it impacted students' writing performance positively (e.g., Gallagher et al., 2017; Wolbers et al., 2017). On the other hand, our predictions regarding time for practice writing and time to teach foundational and process writing skills were more exploratory. As previously reviewed here, evidence from intervention studies substantiates the claim that time for writing practice and time to teach foundational and process writing skills affects writing performance (e.g., Graham & Perin, 2007; Graham et al., 2012a). However, non-interventional research found that, apart from generative writing practice (open-ended writing tasks), the amount of writing practice had no effects on Year 1 students' writing performance. Overall, findings from observational (Coker et al., 2018) and cross-sectional research (De Smedt, 2016) found no effects of teachers' instructional writing practices on students' performance. Several national surveys have reported that keyboarding instruction is a rare occurrence across primary grades (e.g., Gilbert & Graham, 2010), including in Australia (de Abreu Malpique et al., 2022). Hence, we anticipated that teachers would report allocating little time to teach keyboarding, with subsequent null effects on students' keyboarded compositions.

5. Method

5.1. Participants and setting

Invitation letters were sent to 390 government-funded schools, 79 independent schools, and nine catholic schools within the Perth Metropolitan Region, Western Australia. A convenience sample was recruited from the 17 schools that agreed to take part in the first two weeks of recruitment. The Index of Community Socio-Educational Advantage (ICSEA), calculated on the basis of the socioeconomic status of each school's intake area (ACARA 2012), was used to evaluate the socio-demographic representativeness of the participating schools. Schools represented different levels of economic advantage following the ICSEA average (1000), with six schools within the average range (950–1050) and 11 schools above average range (>1050). Enrolment of Indigenous students ranged from 0 to 12 % ($M = 2.8$, $SD = 2.9$) and the percentage of students with language backgrounds other than English ranged from 7 to 47 % ($M = 18.3$, $SD = 10.3$). National and state results on Year 3 students' writing performance collected in the Australian National Assessment Program, Literacy and Numeracy (NAPLAN) (ACARA, 2019) were used to evaluate the representativeness of the participating schools in terms of writing performance. Year 3 results represent the earliest NAPLAN assessment, also repeated in Years 5, 7, and 9. The recruited sample included three schools below and 14 schools above the NAPLAN writing national average results (422.5) and two schools below and 15 schools above the state's NAPLAN writing average results (419.4).

The current study involved 544 Year 2 students with no identified special educational needs ($Mage = 7.00$, $SD = 0.27$; range = 6–8 years; 54.2 % female) enrolled in 47 classrooms from the 17 participating schools. Before participation in the study, written informed consent was obtained from each student and their primary guardian. Within the schools, a total of 46 teachers (all female), ranging from one to seven teachers per school, agreed to participate in this study. The majority (84.8 %) held a bachelor's degree and 10.9 % held graduate degrees. Teachers varied extensively in terms of their professional experience ($Myears = 12.89$, $SD = 10.86$, range = 1–42 years).

5.2. Procedures

The analyses here reported are a component of a larger project examining Year 2's writing achievement and instruction (Malpique et al., 2023; Valcan et al., 2023b). Assessment protocols and task administration were piloted with a group of children (n = 49) prior to

the commencement of this study (Malpique et al., 2023).

Student-level data was collected in the second semester of the school year in two assessment sessions. Session one (individually) included the assessment of children's keyboarding automaticity, literacy skills, attitudes towards writing, and executive functioning, taking approximately 45 min. Session two (groups of three children) included the assessment of children's keyboarded compositions (i.e., writing quality and text length), taking approximately 15 min. Data was collected in a quiet location outside the classroom during the school day. Length, times, and venues for the assessment sessions were negotiated with the teachers, ensuring children's comfort and appropriate levels of monitoring as judged by each setting. The first and second authors administered the tasks, along with three trained research assistants (RAs). Task administration was standardised and ensured using well-developed and defined assessment protocols.

6. Student-level measures

6.1. Keyboarding automaticity

The alphabet writing task (Berninger & Rutberg, 1992) was used to measure keyboarding automaticity. Used in previous studies measuring automatic letter production via keyboarding in Years 2, 4, and 6 (Berninger et al., 2009) and Years 8 and 9 (Christensen, 2004), the score indicates automaticity in recovering alphabetical letters from memory and speed in producing letters in the correct sequence. Students were given a laptop running a Microsoft Windows operating system and were asked to type the 26 letters of the alphabet in alphabetical order as quickly as they could. Consistent with prior research (e.g., Berninger et al., 2009), students received a score of one point for each correctly typed and sequenced letter produced in 15 s. Letters were scored as incorrect if they were out of the alphabetical order. A RA trained to use this assessment instrument in the pilot study of the project scored all protocols. Two members of the research team rescored 50 % of protocols. Inter-rater reliability was calculated using intraclass correlation coefficients, yielding a score of 0.99.

7. Word reading, reading comprehension, and spelling skills

The Word Reading, Reading Comprehension, and Spelling subtests of the Wechsler Individual Achievement Test (WIAT- III) Australian and New Zealand Standardised (Wechsler, 2016) were used to assess children's literacy skills. The Word Reading subtest measures speed and accuracy of word recognition without the aid of context. The subtest is categorised under morphology types, vowel types and consonant types, with items measuring specific word recognition skills, including common prefixes and suffixes as well as vowels and consonant diagraphs. Following directions from the examiner's manual, students were asked to read out loud a list of increasingly difficult words without context, and scores reflected the words that students were able to read accurately. The Reading Comprehension subtest measures reading comprehension of various types of texts similar to those used in school settings (e.g., fictional stories, informational text, advertisements). To complete the test, students were asked to read year-level passages out loud or silently and respond to comprehension questions asked out loud by the examiner. The Spelling subtest measures written spelling of letter sounds and single words from dictation. To complete the test, students were asked to write a target sound or word after listening to the sound or word by itself and in the context of a sentence. Studies testing the validity of the WIAT-III, including content, construct, and criterion-related evidence confirm that the instrument composites and subtests adequately measure each construct, with moderate to high correlations with other literacy achievement test scores (Pelling & Burton, 2017). Two members of the research team rescored 50 % of the word reading, reading comprehension, and spelling subtests and inter-rater reliability was high (ICC = 1.0 for reading comprehension and spelling subtests; ICC = 0.99 for word reading subtest).

8. Attitudes towards writing

Considering the lack of instruments specifically assessing children's attitudes towards keyboard-based writing (Ekholm et al., 2018) and the developmental needs of young cohorts (Graham et al., 2012a), we used semi-structured interviews to assess children's attitudes toward writing in general and keyboard-based writing. As part of the larger research project investigating Year 2 students' writing performance, children were prompted to complete a 15 questions survey examining students' writing attitudes and practices. For the purpose of the current study analyses, we used three questions assessing children's attitudes toward writing: Question 1: *How much do you like writing?*; Question 2: *How much do you like writing using a keyboard?*; Question 3: *How do you feel when you are asked to write a story using a keyboard?*. These questions and the method to quantify students' responses were adapted from the Writing Attitude Survey (WAS) (Kear et al., 2000). Children were asked to circle a variety of options in the form of emotions using a face emoji scale ranging from awful (1) to fantastic (5). A supplementary question asked students to try to explain the reason for their choice (i.e., *Why so?*). To cater for the developmental needs of this cohort, questions were read aloud by the researchers and open-ended responses were audio-recorded. A factor analysis of the three questions produced one factor with an eigenvalue greater than 1.0 explaining 55 % of variance. Questions 2 and 3 loaded at 0.85 and 0.88, respectively (coefficient alpha = 0.74), and question 1 factor loading was below 0.60. Given that question 1 diverged conceptually from questions 2 and 3 and that research recommends the use of single items when a construct is unambiguous in nature and theoretically relevant (Allen et al., 2022; Fuchs & Diamantopoulos, 2009), we decided to keep question 1 to assess children's general attitudes towards writing. Children's attitudes towards keyboarding reflected the average scores of questions 2 and 3. Two members of the research team rescored 50 % of protocols and inter-rater reliability was high (ICC = 0.98).

9. Executive functioning

The Head-Toes-Knees-Shoulders (HTKS) (Ponitz et al., 2008) task was used to assess children's executive functioning (EF). The HTKS task requires children to do the opposite of what the researcher says and consists of three parts, each comprising 10 items. The indicator of EF is the sum of scores for each of three parts (range 0–60). The HTKS task has been conceptualised by Ponitz et al. (2008) as a measure of inhibition (a child is required to inhibit the dominant response of imitating the examiner), attention shifting (a child is required to switch between the rules of the task), and working memory (a child is required to remember the rules of the task). The HTKS correlates with other reputable EF assessments and is a strong indicator in latent variable models of EF (Allan & Lonigan, 2011; Schmitt et al., 2017; Valcan et al., 2020). It has good inter-rater reliability (k = 0.90; Ponitz et al., 2009; McClelland & Cameron, 2012) and strong predictive and concurrent validity (Cameron et al., 2019; McClelland et al., 2007, 2014; Ponitz et al., 2009). In the current sample, the HTKS demonstrated concurrent validity, significantly correlating with the well validated Wechsler Individual Achievement Test, namely on word reading, reading comprehension and spelling (please see Table 1). For the current study, two members of the research team rescored 50 % of protocols and inter-rater reliability was high (ICC = 0.99).

10. Keyboarded composition

Children were given the following prompt for story writing using a keyboard: "On my way home from school, I found a spaceship". Children were given a laptop running a Microsoft Windows operating system with spelling and grammar checks turned off and were given 10 min to write

Table 1
Descriptive statistics and bivariate correlations for student-level (n = 544) measures.

Variable	M	SD	Min-Max	Skewness	Kurtosis	1	2	3	4	5	6	7	8	9	10
1. Gender (Male = 1)	0.46	0.50	0 – 1	−0.17	−1.98	1									
2. General attitudes	3.95	0.89	1 – 5	−0.79	0.88	0.21**	1								
3. KB attitudes	4.02	0.97	0 – 5	−0.88	0.04	0.05	0.15**	1							
4. KB automaticity	8.89	4.39	0 – 24	0.59	0.05	0.11*	0.17**	0.20**	1						
5. Spelling	99.99	14.17	49 – 158	−0.40	1.90	0.02	0.22**	0.10*	0.47**	1					
6. Reading comprehension	68.22	8.41	0 – 81	−2.56	15.13	0.10*	0.09*	0.04	0.30**	0.52**	1				
7. Word reading	104.24	16.47	63 – 150	0.21	−0.50	−0.03	0.16**	0.06	0.45**	0.79**	0.58**	1			
8. Executive functioning	51.41	7.83	0 – 60	−1.90	6.93	0.08	0.07	0.05	0.18**	0.32**	0.37**	0.33**	1		
9. Compositional fluency	39.90	28.22	0 – 211	1.78	4.68	0.14**	0.14**	0.15**	0.53**	0.40**	0.25**	0.42**	0.13**	1	
10. Compositional quality	21.69	5.47	1 – 41	−0.53	2.20	0.11*	0.017**	0.13**	0.50**	0.51**	0.38**	0.53**	0.15**	0.71**	1

Note. KB = keyboarding. $^{*}p < 0.05$. $^{**}p < 0.01$.

their stories. When children stopped writing before the time limit, they were given a maximum of two prompts to write more ("*What else can you think of?*"). After task completion, the examiners asked children to identify words they could not decipher due to unconventional spelling and recorded the intended word for later data analyses (see Berninger et al. 2009, for similar procedures).

Keyboarded compositions were assessed in two different ways. An analytical scoring procedure was used to assess compositional quality. Children's compositions were scored on 10 criteria namely: 1. Audience (e.g., capacity to orient, engage, and affect the reader); 2. Ideas (e.g., development of main idea); 3. Text structure (e.g., beginning, middle, and end); 4. Character and setting (e.g., capacity to portray and develop characters and/or time and atmosphere); 5. Vocabulary (e.g., interesting and specific words to convey meaning); 6. Cohesion (e.g., use of grammatical elements to link parts of the text); 7. Paragraphing (e.g., segmenting of text into paragraphs); 8. Sentence structure (e.g., sentence-level grammar and flow); 9. Punctuation and capitalisation; and 10. Spelling (e.g., spelling of grade-level words). Scores for each criterion were allocated from 1 (*low quality*) to 5 (*high quality*), and the writing quality score reflected the average of the 10 marking criteria (range 0–50). The marking criteria were adapted from the Australian National Assessment Program, Literacy and Numeracy (NAPLAN) narrative writing marking (ACARA 2016) and from the widely used 6 + 1 Trait® Writing rubric for Primary Grades (NREL, 2011) since these measures are well aligned with Year 2 curriculum-based judging standards for writing and creating texts in Western Australia (School Curriculum and Standards Authority [SCSA], 2016). Moreover, NAPLAN's narrative writing marking guide is used to assess high-stakes online tests in Australia. Hence, using an adapted analytical scoring scale promised to add ecological validity to the current study (please see Appendix A for a more comprehensive view of the adapted analytical scoring scale). Two RAs, a primary school teacher blind to the purpose of this study and a PhD student, were trained to use the rating scale. To practice using the scales, raters were provided with anchor texts from high, middle, and low scores obtained from three Year 2 classes that participated in the pilot phase of this study and were encouraged to discuss the distinguishing features of each specific marking criterion. After independently scoring each practice text, raters compared scores and reached a level of agreement through discussion. The primary teacher marked all keyboarded compositions. The first author and the PhD student rescored 50 % of students' texts for compositional quality. Interrater reliability measured by the intraclass correlation coefficient was 0.92 (criteria range = 0.79-0.91). The total number of words (TNW) was used to evaluate compositional fluency. TNW is a widely used measure because it has been shown to predict compositional quality in previous research (e.g., Graham et al., 2016). All words that represented a spoken word were counted, regardless of spelling. The first author and the PhD student rescored 50 % of students' texts for compositional fluency. Interrater reliability measured by the intraclass correlation coefficient was 0.99.

11. Classroom-level measures

After collecting student-level measures, all 47 teachers of the 544 participating students were asked to complete a Likert-type questionnaire providing information about themselves and the writing practices that they had developed with their students during the school year. The survey was adapted from a national survey examining writing instruction in Australian primary classrooms (Years 1–6, typically age 6 to 12) (de Abreu Malpique et al., 2022). The survey included 44 items grouped into four main sections: (1) teacher information (4 items); (2) time for writing practice and teaching writing (3 items); (3) writing activities completed during the school year (1 item); and (4) instructional practices supporting the development of students' writing (39 items). To address the current study's research questions, only the first and second sections of the survey were used for multilevel data analyses. In the first section, we asked teachers to provide demographic information, including their gender, highest educational level and years spent teaching. Teachers were also asked to rate the quality of their pre-service and in-service preparation to teach writing, and to name any commercial programs they were using to teach writing skills, including keyboarding programs. In the second section, teachers were asked to indicate how much time they allocated to writing practice in their classrooms and how much time they allocated to teaching foundational skills (i.e., handwriting, keyboarding, spelling, and grammar usage) and process writing skills (i.e., revision strategies and planning strategies) on a weekly basis. The reported reliability coefficient of the items examining the amount of time for teaching foundational skills and teaching writing processes, as assessed by Cronbach's alpha, was 0.79 and 0.81, respectively (de Abreu Malpique et al., 2022). In the current study, Cronbach's alpha values for teaching foundational skills and teaching writing processes were 0.71 and 0.77, respectively.

12. Data analysis strategy

Because of the nested nature of the data, we employed multilevel modelling to account for the dependence among the observations (Raudenbush & Bryk, 2002). It has been demonstrated in the literature that at least 30 groups are needed to obtain unbiased 2-level MLM parameter estimates (Bell et al., 2014; Maas & Hox, 2004). We specified a two-level hierarchical structure for our MLM analyses in which students represented the lower level of analysis (level 1) and classrooms represented the upper-level clustering variable (level 2).

A series of multivariate hierarchical linear models were applied via a four-step model constructing process for each outcome variable, namely keyboarding compositional quality and keyboarding compositional fluency. First, a null (baseline) model (Model 0) (Kreft & de Leeuw, 1998) was tested with no predictors at the student and school levels. The null model served as a baseline model to examine whether variability occurred at the classroom level and, if so, how much of the total variability (ICC, intraclass correlation coefficient) in compositional quality and compositional fluency could be attributed to the differences among classrooms. This model partitions total variance into within-classroom and between-classroom variance components and indicates whether classrooms vary significantly from each other. Second, a student-level model (Model 1) was estimated as a function of student-level predictors. The effects of classroom-level variables were not included in this model. In a second model (Model 2), we estimated classroom-level effects to explore the relationships between outcome measures and teachers' preparation and instruction practices. Both student and classroom-level predictors were added to Model 2. Finally, a cross-level interaction model (Model 3) was estimated to investigate whether the relationship between student-level factors and keyboard-based writing depended on classroom-level factors. We tested interaction effects separately with their corresponding main effects. After identifying significant interactions, we then jointly tested them all again and eliminated nonsignificant interactions if there were any. Thus, in our final model (Model 3), only significant interactions were reported.

This study included an average of 11.57 students per classroom. Number of students in classrooms ranged from 2 to 23. Multilevel models were estimated using Restricted Maximum Likelihood Estimation (REML) estimator, which produces less biased estimates with small samples (Boedeker, 2017). We estimated all multilevel models with HLM 7 software (Raudenbush et al., 2011) using robust standard errors. We group-mean centred student-level variables and grand-mean centred classroom-level predictors. To be able to disaggregate between- and within-person effects, group means were entered as predictors at Level 2 (Curran & Bauer, 2011; Raudenbush & Bryk, 2002; Newsom, 2017). Both intercepts and slopes were allowed to vary across classrooms since leaving out random slopes might result in false statistical conclusions concerning cross-level interactions (Heisig & Schaeffer, 2019). We reported unstandardised coefficients, which can be interpreted as the increase in outcome variable per one-unit increase in the predictor when all other variables in the model are held constant.

13. Results

Descriptive statistics and bivariate correlations for student-level measures are presented in Table 1, including skewness and kurtosis values. Descriptive statistics and bivariate correlations for classroom-level measures are presented in Table 2, including average scores for pre-service and in-service preparation, weekly amount of time in minutes for writing practice and instructional practices, and corresponding skewness and kurtosis values. It is worth mentioning that the majority of student and classroom-level variables followed a normal distribution, although some specific predictors exhibited non-normality. However, it is imperative to emphasize that these deviations did not significantly influence our analytical methods. This observation is in line with previous research (e.g., Man et al., 2022) showing that fixed effects remain unbiased even in the presence of residuals that deviate from the normal distribution.

13.1. Keyboarding compositional quality

Parameter estimates and standard errors resulting from multilevel analyses are summarised in Table 3 for the keyboarding compositional quality model specifications. Results of the baseline (null) model showed significant variations in intercepts, indicating that mean keyboarding compositional quality scores varied significantly ($\chi 2\ (46) = 121.33$, $p < 0.001$) across classrooms. Belonging to a particular classroom accounted for 13 % of the variation in children's keyboarding compositional quality outcomes.

The student-level model (Model 1) indicated significant associations between general attitudes ($\beta = 0.313$, $p < 0.05$), keyboarding automaticity ($\beta = 0.322$, $p < 0.001$), spelling ($\beta = 0.059$, $p < 0.05$), reading comprehension ($\beta = 0.065$, $p < 0.05$), word reading ($\beta = 0.085$, $p < 0.001$) and gender ($\beta = –0.776$, $p < 0.05$), with females performing better than male students. The classroom-level model (Model 2) revealed that the effects of classroom-level variables were not significant except for time teaching handwriting, which was negative ($\beta = –0.034$, $p < 0.05$).

The cross-level interaction model (Model 3) pointed out some significant interactions between student and classroom-level variables. At the student-level, general attitudes ($\beta = 0.347$, $p < 0.05$), keyboarding automaticity ($\beta = 0.314$, $p < 0.001$), spelling ($\beta = 0.052$, $p < 0.05$), and

Table 2
Descriptive statistics and bivariate correlations for classroom-level (n = 47) measures.

Variable	M	SD	Min-Max	Skewness	Kurtosis	1	2	3	4	5	6	7	8	9
1. Pre-service preparation	2.55	0.90	1 – 4	-0.07	-0.69	1								
2. In-service preparation	3.62	0.82	1 – 5	−1.13	1.52	0.14	1							
3. Time practice writing [a]	188.23	124.30	60 – 660	1.65	3.13	−0.25	0.32**	1						
4. Time teaching spelling [a]	120.17	57.63	40 – 270	0.92	-0.04	0.12	−0.08	0.26	1					
5. Time teaching handwriting [a]	42.02	19.30	0 – 90	0.21	0.84	0.65	0.12	0.15	0.39**	1				
6. Time teaching keyboarding [a]	28.00	38.33	0 – 240	3.80	20.18	0.19	0.08	0.17	0.39**	0.24	1			
7. Time teaching grammar [a]	67.89	65.65	0 – 360	3.08	10.75	−0.17	0.07	0.19	0.20	0.31*	0.00	1		
8. Time teaching planning strategies [a]	37.47	33.67	0 – 120	1.38	1.65	0.08	0.05	0.39**	0.36*	−0.03	0.46**	0.21	1	
9.Time teaching revision strategies [a]	40.51	53.48	0 – 360	4.82	28.50	−0.16	0.07	0.29**	0.25	0.05	0.11	0.54**	0.53**	1

Note. a = minutes per week.
*$p < 0.05$. **$p < 0.01$.

Table 3
Multilevel results of keyboarding compositional quality measure.

	Model 1	Model 2	Model 3
Level-1 predictors (student)			
Gender (*male*)	–0.776 (0.366)*	–0.766 (0.381)*	–0.651 (0.325)*
General attitudes	0.313 (0.156)*	0.333 (0.156)*	0.347 (0.151) *
KB attitudes	0.059 (0.162)	0.064 (0.160)	0.060 (0.151)
KB automaticity	0.322 (0.052)***	0.322 (0.053)***	0.314 (0.044) ***
Spelling	0.059 (0.025)*	0.058 (0.024)*	0.052 (0.022) *
Reading comprehension	0.065 (0.030)*	0.062 (0.030)*	0.058 (0.030)
Word reading	0.083 (0.023)**	0.084 (0.023)**	0.094 (0.022) ***
Executive functioning	–0.004 (0.020)	–0.001 (0.019)	–0.002 (0.019)
Level-2 predictors (classroom)			
Pre-service preparation		–0.128 (0.291)	–0.169 (0.291)
In-service preparation		–0.055 (0.317)	–0.002 (0.322)
Time practice writing		–0.004 (0.003)	–0.004 (0.003)
Time teaching spelling		0.010 (0.006)	0.011 (0.006)
Time teaching handwriting		–0.034 (0.013)*	–0.034 (0.013)*
Time teaching revision		–0.000 (0.005)	–0.001 (0.005)
Time teaching grammar		–0.001 (0.005)	–0.002 (0.005)
Time teaching planning		–0.010 (0.007)	–0.008 (0.007)
Time teaching keyboarding		0.004 (0.005)	0.005 (0.005)
Cross level interactions			
Gender* Time teaching keyboarding			–0.021 (0.004)***
KB attitudes* Time teaching planning			–0.011 (0.004)**
KB automaticity* Time teaching revision			0.002 (0.000) ***
Spelling* Time teaching planning			–0.001 (0.000)**

Notes. KB = keyboarding, robust standard errors are in parentheses.
* p < 0.05, ** p < 0.01, *** p < 0.001.

word reading ($\beta = 0.094$, $p < 0.001$) maintained significant positive main effects while the main effect of reading comprehension was not significant. In relation to the main effect of gender, females significantly outperformed males ($\beta = –0.651$, $p < 0.05$) in compositional quality. At the classroom level, the main significantly negative effect of time teaching handwriting ($\beta = –0.034$, $p < 0.05$) was sustained. In relation to cross-level interactions, we found that time teaching keyboarding had significantly positive effects ($\beta = –0.021$, $p < 0.001$) on the relationship between gender and keyboarding compositional quality. In other words, in classrooms allocating more time teaching keyboarding, the gender gap in keyboarding compositional quality among students was larger in favour of female students. Cross-level interactions indicated that the effects of keyboarding attitudes ($\beta = –0.011$, $p < 0.01$) and spelling ($\beta = –0.001$, $p < 0.01$) were significantly larger for classrooms with less time spent on teaching planning. We also found that the effects of keyboarding automaticity on keyboarding compositional quality depended on the time spent teaching revision. Specifically, the effects of keyboarding automaticity were significantly larger ($\beta = 0.002$, $p < 0.001$) in classrooms in which teachers spent more time teaching revision.

14. Keyboarding compositional fluency

Multilevel results for the keyboarding compositional fluency model are summarised in Table 4. Results of the baseline (null) model showed significant variations in intercepts, indicating that mean keyboarding compositional fluency scores varied significantly ($\chi 2\ (46) = 138.62$, $p < 0.001$) across classrooms. Belonging to a particular classroom accounted for 16 % of the variation in children's keyboarding compositional fluency scores. In comparison to the compositional quality, there was more variation among classrooms in compositional fluency.

The student-level model (Model 1) indicated significant associations between keyboarding automaticity ($\beta = 2.276$, $p < 0.001$), word reading ($\beta = 0.332$, $p < 0.001$) and gender ($\beta = –6.148$, $p < 0.01$), with females outperforming males. After controlling for student-level variables, the classroom-level model (Model 2) showed that pre-service preparation ($\beta = –2.572$, $p < 0.05$), time teaching writing ($\beta = –0.029$, $p < 0.01$), time teaching handwriting ($\beta = –0.200$, $p < 0.01$), and time teaching keyboarding (($\beta = 0.063$, $p < 0.01$) significantly predicted students' keyboarding compositional fluency scores.

The final cross-level interaction model (Model 3) revealed some

Table 4
Multilevel results of keyboarding compositional fluency measure.

	Model 1	Model 2	Model 3
Level-1 predictors (student)			
Gender (*male*)	–6.148 (2.112)**	–6.358 (2.260)**	–5.571 (2.000)**
General attitudes	0.719 (1.321)	0.451 (1.390)	0.574 (1.270)
KB attitudes	1.361 (0.774)	1.341 (0.784)	1.192 (0.682)
KB automaticity	2.276 (0.370)***	2.296 (0.362)***	2.305 (0.343) ***
Spelling	0.071 (0.088)	0.067 (0.082)	0.043 (0.086)
Reading comprehension	0.088 (0.129)	–0.080 (0.136)	–0.140 (0.124)
Word reading	0.332 (0.083)***	0.354 (0.088)***	0.388 (0.088) ***
Executive functioning	0.094 (0.096)	0.168 (0.095)	0.150 (0.100)
Level-2 predictors (classroom)			
Pre-service preparation		–2.572 (1.186)*	–2.441 (1.223)
In-service preparation		0.935 (1.284)	0.756 (1.307)
Time practice writing		–0.029 (0.001)**	–0.027 (0.010)**
Time teaching spelling		0.032 (0.021)	0.031 (0.021)
Time teaching handwriting		–0.200 (0.059)**	–0.219 (0.060)**
Time teaching revision		0.031 (0.023)	0.052 (0.026)
Time teaching grammar		–0.017 (0.014)	–0.015 (0.014)
Time teaching planning		–0.040 (0.043)	–0.072 (0.045)
Time teaching keyboarding		0.063 (0.017)**	0.072 (0.017) ***
Cross level interactions			
Gender* Time teaching keyboarding			–0.141 (0.024)***
General attitudes* Time teaching grammar			–0.036 (0.010)**
KB attitudes* Time teaching planning			–0.078 (0.015)***
KB automaticity* Time teaching revision			0.011 (0.002) ***
Spelling*Time teaching planning			–0.005 (0.001)*

Notes. KB = keyboarding, robust standard errors are in parentheses.
* p < 0.05, ** p < 0.01, *** p < 0.001.

significant interactions between student and classroom-level variables. At the student-level, keyboarding automaticity ($\beta = 2.305$, $p < 0.001$) and word reading ($\beta = 0.388$, $p < 0.001$) maintained significant positive main effects. In relation to the main effect of gender, females performed significantly better than male students ($\beta = –5.571$, $p < 0.01$) in keyboarding compositional fluency. At the classroom level the main effects of time teaching writing ($\beta = –0.027$, $p < 0.01$), time teaching handwriting ($\beta = –0.219$, $p < 0.01$), and time teaching keyboarding ($\beta = 0.072$, $p < 0.001$) were sustained while the main effect of pre-service preparation was not significant. Among these, the relationship between the time that teachers allocated to teaching keyboarding and keyboarding compositional fluency was positive while the other two coefficients were negative.

Regarding cross-level interactions, we found that the effects of time teaching keyboarding were significantly larger ($\beta = –0.141$, $p < 0.001$) for female students in classrooms with greater time spent teaching keyboarding. Even though the main effects of general attitudes, keyboarding attitudes, and spelling were not significant, there were some significant interactions between these predictors and the classroom level variables. We found that the effect of general attitudes on keyboarding compositional fluency was significantly smaller ($\beta = –0.036$, $p < 0.01$) for classes in which teachers spent more time teaching grammar. The interaction terms between keyboarding attitudes - time teaching planning ($\beta = –0.078$, $p < 0.001$) and spelling - time teaching planning ($\beta = –0.005$, $p < 0.05$) were negative indicating that the effects of keyboarding attitudes and spelling were larger in classrooms allocating less time teaching planning. We also found that the effects of keyboarding automaticity on keyboarding compositional fluency depended on the time teaching revision. Specifically, the effects of keyboarding automaticity were significantly larger ($\beta = 0.011$, $p < 0.001$) in classrooms where teachers reported allocating more time teaching revision.

Additional independent *t*-test results showed gender differences favouring female students in keyboarding automaticity ($t(542) = -2.53$, $p = 012$, $d = 0.22$); general attitudes toward writing ($t(542) = -4.96$, $p = 000$, $d = 0.43$); and reading comprehension ($t(542) = -2.30$, $p = 022$, $d = 0.19$).

15. Classroom-level factors

15.1. Preparation to teach writing

The majority of teachers were positive about their pre-service preparation to teach writing (Table 2). Most teachers reported having received adequate pre-service training to teach writing (38.3 %), while 14.9 % reported that their pre-service preparation was very good. However, 46.8 % of teachers reported that their undergraduate preparation was poor (34 %) or inadequate (12.8 %). Teachers seemed more positive about their in-service preparation to teach writing. A high percentage of teachers reported they had received a very good in-service training to teach writing (61.7 %), with another 6.4 % reporting it as exceptional and 21.3 % as adequate. Fewer teachers reported having received poor (8.5 %) and inadequate (2.1 %) in-service preparation for teaching writing.

15.2. Amount and types of writing instruction

On average, teachers reported that their students spent approximately three hours a week on writing practice in their classroom (Table 2). Regarding the teaching of foundational skills, teachers reported allocating more time a week teaching spelling than the other foundational skills, namely teaching handwriting ($t(46) = 9.30$, $p = 000$, $d = 1.89$); teaching grammar ($t(46) = 6.22$, $p = 000$, $d = 0.85$); and teaching keyboarding ($t(46) = 10.96$, $p = 000$, $d = 1.88$). Teachers also reported allocating more time a week teaching grammar than teaching handwriting ($t(46) = 2.70$, $p = 0.010$, $d = 0.53$) and keyboarding ($t(46) = 4.17$, $p = 0.000$, $d = 0.74$); and more time a week teaching handwriting than keyboarding ($t(46) = 4.98$, $p = 0.000$, $d = 0.46$). Time devoted to teaching process writing skills was less than for teaching foundational skills, expect for teaching keyboarding. On average, teachers reported allocating more time teaching spelling than teaching planning ($t(46) = 9.84$, $p = 0.000$, $d = 1.75$) and revision strategies ($t(46) = 9.48$, $p = 0.000$, $d = 1.43$); more time teaching grammar than teaching planning ($t(46) = 3.18$, $p = 0.003$, $d = 0.58$) and revision strategies ($t(46) = 2.86$, $p = 0.006$, $d = 0.46$). Finally, 19.14 % of teachers reported using commercial programs to teach keyboarding.

16. Discussion

In the present study, we investigated the extent of student and classroom-level variables explaining Year 2 students' keyboard-based writing performance. Aligned with the WWC model and its proposed cognitive architecture for writing (Graham, 2018), the first goal of this study was to examine the role of transcription skills (keyboarding automaticity and spelling), reading skills (word reading and reading comprehension), attitudes towards writing, executive functioning, and gender in predicting Year 2 students' keyboard-based writing performance (compositional quality and fluency). As per the WWC model (Graham, 2018), effective writing instruction plays a fundamental role in supporting writing acquisition and development, and it is particularly important in early education as a strong foundation for the development of effective writing skills (Graham, 2019). Hence, a subsequent aim of this study was to examine if the relations between student-level and keyboard-based writing depended on classroom-level factors, namely teachers' perceived preparation for teaching writing, amount of writing practice, and the amount and type of writing instruction. The two goals aligned with the WWC organising structure are discussed in turn in the following sections.

16.1. Student-level factors predicting keyboard-based writing performance

The findings from the present study confirm and extend previous studies by showing how transcription skills, reading skills, attitudes toward writing and gender are related to compositional quality and compositional fluency via keyboard. As expected, students' keyboarding automaticity significantly predicted compositional quality and fluency, confirming the outcomes of previous studies in handwriting, and stressing the importance of developing automaticity to free the necessary cognitive resources to devote to more complex processes such as ideation and text generation. As anticipated, the other transcription-related variable, spelling, was also found to positively predict compositional quality via keyboard. Students' spelling skills, however, did not uniquely predict compositional fluency. Our results are aligned with previous research reporting stronger relationships between handwriting automaticity and compositional fluency than spelling in handwritten texts in Years 1 through Year 3 (Graham et al., 1997). Current findings also offer empirical support to the WWC model (Graham, 2018), in which production processes, including transcription skills, are said to impact writing performance outcomes.

Our results further revealed that students' general attitudes toward writing predicted compositional quality via keyboard, offering further empirical support to the WWC model (Graham, 2018) and its contention that individual writers' favourable or unfavourable writing attitudes may lead to positive or negative responses to writing tasks, subsequently impacting writing outcomes. This finding also contributes to the body of evidence establishing relationships between motivational factors, including attitudes toward writing and the writing performance in primary education (Ekholm et al., 2018). However, our analyses revealed that attitudes toward composing keyboarded texts did not predict students' compositional performance. This finding was somewhat surprising since findings from the pilot phase of this study (Malpique et al., 2023) showed moderate associations between children's attitudes

toward composing keyboarded texts, compositional quality (0.42) and compositional fluency (0.44) via keyboard. As previously reviewed here, prior research on primary students' attitudes towards writing suggests a complex picture regarding relations between writing attitudes and writing performance (e.g., Graham et al., 2012a; Olinghouse & Graham, 2009), which signals the need for more research in this area.

Gender was uniquely related to the keyboarded compositions of Year 2 students, with female students outperforming their male peers in both compositional quality and fluency measures. Given the strong body of research reporting a male advantage in overall computer-based performance and attitudes towards technology (Cai et al., 2017) and research repeatedly reporting relationships between writing performance and attitudes toward writing in primary education (e.g., Ekholm et al., 2018), we anticipated gender effects favouring male students on keyboarding composition. Findings from our analyses, however, further revealed statistically significant differences between genders in other student-level factors favouring females. In other words, female students were able to produce longer and higher quality keyboarded compositions; were more automatic in letter writing via keyboard; exhibited higher levels of general attitudes toward writing; and higher levels of reading comprehension skills. While these findings are convergent with previous research showcasing a pattern of female advantage on handwritten composition variables (e.g., Skar et al., 2022), on general attitudes towards writing (e.g., Ekholm et al., 2018), and reading comprehension (Logan & Johnston, 2010), they extend knowledge on gender differences in keyboarding composition. Gender differences in writing have been connected to biological factors, including more advanced development in fine motor skills and language skills (Hartley, 1991; Reilly et al., 2019); neural level differences in handwriting, namely the different utilisation of the Exner's area, a writing-specific brain region (Yang et al., 2020); and cultural expectations, including society expectations that female students have better handwriting and are better writers than their male counterparts (Spear, 1989).

Our findings further showed that students' reading skills were uniquely related to compositional quality via keyboard, offering additional support for the WWC model's contention that reading is a central factor impacting writing performance (Graham, 2018). To the best of our knowledge, this is the first study with a large sample of typically developing children showing that students' reading skills at the word and text levels facilitate keyboarded composition, even after accounting for keyboarding automaticity, spelling, and other student-level factors, including motivational factors and gender. After controlling for classroom-level factors, however, only word reading maintained significantly positive effects on compositional quality and fluency, suggesting that reading skills may influence keyboard-based text composing in specific ways. While our findings offer some preliminary evidence that children's word reading abilities, which are expected to become automatised earlier than reading comprehension skills (Leppänen et al., 2005), play a more prominent role in predicting the keyboard-based writing of beginning writers, future research is this area is warranted.

Finally, students' executive functioning failed to predict keyboard-based compositional quality and compositional fluency. Previous research found that, especially in young writers, transcription skills (e.g., handwriting automaticity) may hinder the contribution of EF to text composing, as lack of automaticity consumes most of the available cognitive resources (Berninger et al., 2006). Drijbooms et al. (2015) tested the possibility of EF influencing handwritten composition via transcription skills (e.g., handwriting automaticity). Indeed, results showed that EF contributed indirectly to handwritten composition via handwriting automaticity. This indirect pathway was also demonstrated in a longitudinal study (Valcan et al., 2020), in which kindergarten children's EF skills contributed to their handwritten composition via handwriting automaticity in Year 1. These findings potentially reflect the role of executive control in the coordination of multiple processes during handwriting. As postulated in the WWC model (Graham, 2018), control mechanisms such as EF potentially shape production processes involved in composing texts, including keyboarding skills, subsequently impacting final written products. Hence, while we did not test any indirect effects in the current study, it seems possible that students' EF skills could be impacting keyboard-based writing indirectly via keyboarding automaticity.

16.2. Classroom-level factors predicting keyboard-based writing performance

Findings from the current study show some significant interactions between student and classroom-level variables, offering empirical support for the WWC model (Graham, 2018) and its main proposal that "writing is shaped by both the capacity of the writing community and the capabilities of its members" (Graham et al., 2018b, p. 273). Our results also confirm and expand the limited non-interventional research examining relationships between writing instruction and writing achievement in primary education (Coker et al., 2018; De Smedt et al., 2016). Namely, results showed a positive impact of amount of time teaching keyboarding on compositional fluency. Of note is the fact that data collection took place in the last two terms of the school year, so it would be logical to expect that teachers would be allocating more time on compositional processes, which could also impact the compositional quality of keyboard-based texts. Our findings, however, suggest that when the instructional focus is placed on keyboarding, this is directed to developing automatisation rather than keyboard-based texts of quality. Our survey results tend to indirectly support this line of reasoning. They show that the three most prevalent teaching foci were spelling, grammar, and handwriting, while the least three prevalent ones were revision, planning, and keyboarding. These findings suggest teachers' emphasis on transcription skills, which may operate at the expense of teaching process skills necessary to produce quality texts. This rationale would also be in line with our findings showing a negative impact of teaching handwriting on both compositional quality and fluency. Though not specific to keyboarding, lack of associations between teaching practice and writing performance have been previously reported (Coker et al., 2018; De Smedt et al., 2016). The study by Coker et al. (2018) is an interesting example not only because of its observational methods but because of its focus on the nature of activities promoted by teachers. In this study, only *generative writing* defined as "creating content and producing connected text" (p. 236) was positively associated with writing performance, suggesting the importance of composition tasks that promote the practice of transcription and process skills simultaneously. While our survey did not ask teachers to describe activity types, the emphasis on transcription skills and handwriting, combined with lower incidences of planning, revising, and keyboarding, may serve to create environments that are not explicitly encouraging children to compose quality keyboard-base texts, at least not to the extent of other writing activities.

Our results also showed that the amount of writing practice reported by teachers did not impact keyboard-based compositional quality and that it was negatively related to compositional fluency. The most plausible, thought tentative, reason for these findings is teachers' placing greater emphasis on pen-and-paper activities when compared to keyboard-based ones. As mentioned, our survey questions did not ask teachers explicitly about the extent of keyboarding practice, but the small percentage of teachers reporting the use of commercial programs to teach keyboarding (19.4 %) may be an indication of the lesser extent to which keyboarding activities may be prioritised in Year 2 classrooms. Multilevel-analyses further showed that Year 2 teachers' preparation to teach writing did not predict their students' keyboard-based writing performance after controlling for student and other classroom-level factors. Research found positive associations between teachers' preparation to teach writing and primary students' writing performance (e.g., Gallagher et al., 2012; Wolbers et al., 2017). While research examining writing instruction in Australia is relatively limited, in a state survey

examining primary teachers' preparation to teach writing in New South Wales, 44 % of primary teachers reported that they were not prepared to teach keyboarding (Wyatt-Smith et al., 2018). Hence, the lack of impact in our study could be attributed to teachers' lack of preparation to teach keyboarding.

Results from cross-level interactions emphasise the complexity of writing and offer empirical support to the WWC model (Graham, 2018) by reinforcing the need to take a multidimensional approach to understanding writing acquisition and development. More specifically, our findings revealed that female students were predicted to have higher scores on both compositional quality and fluency than males in classrooms allocating more time to teaching keyboarding. These findings suggest that the gender gap in keyboard-based writing might be related to keyboarding instruction and teaching practices. Indeed, Coker et al. (2018) observational study examining the impact of writing instruction on Year 1 students' paper-based writing also found interactions between gender and writing practices, with male students predicted to have higher quality and length scores in classrooms allocating more time to generative writing practices. Hence, as Coker and colleagues (2018), we argue that while there is a wealth of studies reporting gender differences in writing explained by student-level factors (e.g., Graham et al., 2007; Lee, 2013; Malpique et al., 2020), gender differences in writing may also be a proxy for other factors, including specific teaching practices.

Our results further showed that allocating more time to teaching planning, revision, and grammar may impact relations between student-level factors and keyboard-based writing. Namely, findings indicated that the effects of keyboarding automaticity on both compositional quality and fluency were larger in classrooms where teachers reported allocating more time teaching revision strategies. Results further showed that the effects of attitudes toward composing keyboarded texts and spelling on both compositional quality and fluency were larger in classrooms where teachers reported allocating less time teaching planning. Finally, the effect of general attitudes towards writing in compositional fluency was smaller in classrooms where teachers reported spending more time teaching grammar. While previous research supports, to some extent, the interpretation of the gender interactions here reported (Coker et al., 2018), future research is needed to disentangle these interaction effects and provide a comprehensive understanding of factors impacting the keyboard-based writing performance of beginning writers. Findings from a mixed methods study comparing the writing scores from NAPLAN online writing tests and paper-based tests (Centre for Education Statistics and Evaluation [CESE], 2021) with a sample of primary students (Years 2–5) in Australian classrooms offer some preliminary explanations for teaching planning and revision interactions effects. More specifically, observations of students while completing computer-based tests revealed that students did little planning to compose their texts. In addition, in subsequent interviews with the students' classroom teachers, most teachers reported that students would more often be prompted to plan and compose their texts using paper and pen, and that computers were only used individually in later publishing and revising stages. While researchers in this study did not analyse interactions between student and classroom-level factors (CESE, 2021), it seems likely that such planning and revision strategies would impact students' keyboard-based writing performance, especially when considering findings from *meta*-analyses on writing showcasing the impact of teaching planning and revising strategies on students' writing performance (e.g., Graham et al., 2012c; Rogers & Graham, 2008). As it occurs with studies targeting relatively underexplored areas, ours serves to generate a number of questions for future research, calling for observational studies that not only look at prevalence of teacher instructional practices but also at the nature of the writing activities or tasks that students are encouraged to engage in.

17. Limitations

While the present study provides important information regarding student and classroom-level factors predicting the keyboard-based writing performance of primary school students, several limitations must be considered when interpreting findings. First, despite assessing several aspects of keyboard-based writing, including compositional quality and fluency, using one writing prompt alone is a limitation of the present study since multiple samples of students' writings could have increased measurement reliability. In addition, writing instruction was assessed via self-reports rather than direct observation of teachers' writing practices. Hence, teachers' responses could have been influenced by the difficulty of estimating time allocated for writing practices and types of instructional practices. To help controlling for these potential effects, teachers were asked to complete their surveys immediately after the collection of students' measures. We reasoned that this option would increase the likelihood of teachers reporting actual practices as opposed to planning writing instruction having our survey in mind (Malpique et al., 2020). In addition, the option of using a self-report instrument limited the potential of examining changes in the types of instructional practices provided. Also, given the paucity of questionnaires assessing writing instruction in Australian primary classrooms, our survey was adapted from a validated questionnaire administered among a national population of Australian primary teachers (de Abreu Malpique et al., 2022). This option, however, restricted the nature of our survey questions. More specifically, teachers' preparation and writing practice questions were general in nature, not specifically focused on keyboarding instruction.

18. Future lines of research

The present study's findings and limitations point to several promising directions for future research. While we have briefly pointed out some recommendations for future research in the previous discussion section, further recommendations are needed when considering the novelty of the findings here reported. First, results from the current study indicated stronger and more direct relationships between keyboarding automaticity and keyboard-based writing performance than spelling. Hence, future research examining interrelationships among transcription processes for keyboard-based text composing is warranted. Second, more research is needed to examine motivational factors related to keyboard-based writing, including attitudes toward writing computer-generated texts. Since writing attitudes is an underdeveloped construct (Ekholm et al., 2018), and given the paucity of studies examining relationships between writing attitudes and performance, mixed method and qualitative studies may offer reasons and important insights explaining children's attitudes toward keyboard-based writing. Third, current findings emphasise the gender gap in writing performance, extend it to keyboard-based writing, and suggest that teaching practices may explain gender differences in keyboard-based text composing. Hence, intervention studies testing the advantages of differentiated instruction and practice are critical to inform evidence-based recommendations for teaching keyboard-based writing. Fourth, in the current study, we were not able to find any direct effects of EF on keyboard-based writing. Considering theoretical grounds arguing for the critical role of control mechanisms in explaining writing acquisition and development (Graham, 2018), as well as empirical evidence suggesting indirect contributions of EF in paper-based text composing (Drijbooms et al., 2015; Valcan et al., 2020), future research testing both direct and indirect effects of EF on keyboard-based writing is warranted. Finally, as previously noted, classroom-level factors were assessed via self-report instrument in the current study. Namely, we asked teachers to report on their overall perceived preparation to teach writing, not on specific preparation to teach keyboarding. Future studies are needed to examine whether results would vary as a function of preparation for keyboarding instruction. Importantly, additional research, including direct observation and interviews, or a combination of the two, is needed to focus on the impact of specific instructional practices for teaching keyboarding on students' writing performance, and provide a more precise

understanding of the nature and the quality of instructional practices supporting keyboard-based writing.

19. Implications and conclusion

Findings from the current study show that student-level factors along with classroom-level factors impact the keyboard-based writing performance of beginning writers. Our study confirmed the importance of automating keyboard transcription skills (McCutchen, 1996) particularly given the changing educational contexts where national literacy instruction standards are now set to be completed in online platforms (Poole & Preciado, 2016). Research on learning and teaching keyboarding skills, however, is scarce and there are no standardised assessments for keyboarding performance (Donica et al, 2018). Aligned with the two basic organising structures of the WWC model for writing (Graham, 2018), the novel findings from this study offer empirical evidence to argue for the need to pay attention to multiple components explaining young students' keyboard-based writing. Since findings showed that gender directly impacts students' keyboard-based compositional skills, it seems particularly relevant to develop differentiated keyboarding instruction and practice in the early years to address a potential gender gap in subsequent years of schooling. For that, it becomes critical to determine what effective keyboarding instruction looks like across the primary years of schooling and inform educational policies and teacher education programs that promote effective writing in the digital age.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A

Analytical Scoring Scale for Keyboard-Based Compositional Quality.

Audience				
1- Low Quality Response to audience needs is limited; may be a title only OR meaning is difficult to access OR copied prompt topic.	2- Below Average Quality The writer's awareness of audience is not clear; may include simple narrative markers (formulaic story opening; reader may need to fill gaps in information).	3- Average Quality Awareness of audience is present in a general way; the writer's feelings about the topic are expressed (e.g. "fun", underlining, use of exclamation points); the writers show some signs of individual expression.	4 – Above Average Quality The writing shows an awareness of audience; the writer's feelings about the subject are identifiable; a sense of the writer's individuality emerges from the text.	5- High Quality Exhibits expectational audience awareness and is compelling to read; Supports and engages the reader through deliberate choice of language and use of narrative devices (fantasy, humour, suspense).
Text Structure				
1- Low Quality Has no obvious structure or organisation. Has no sense of beginning, middle, or end; inappropriate genre (e.g., recipe, argument); title only.	2- Below Average Quality Minimal evidence of narrative structure. Shows a beginning sense of structure in writing, but sequencing is not present or is confusing; may be just description.	3- Average Quality A structure is present, despite being basic or confusing in places. Begins developing a structure through organisation but may still be hard to follow; experiments with a beginning (e.g., "Once upon a time") and/or a middle; includes no clear ending except possibly "The End".	4 – Above Average Quality The structure is easy to follow; includes transitions in the structure. Includes a beginning, middle, and end; uses logical sequencing that can be followed by reader.	5- High Quality Complete and controlled story. Has a beginning, middle, and end that work together to communicate consistently; includes lead and concluding sentences; puts writing in an order that clarifies meaning.
Ideas				
1- Low Quality Does not communicate an idea through writing (uses scribbles or shapes that imitate letters/words; may write letters/words randomly).	2- Below Average Quality Attempts to present the idea, but it is vague. Drawing (if present) may be present but is not related to writing.	3- Average Quality Ideas show some development or elaboration; ideas relate coherently but may contain unnecessary elaboration (waffle). Tries to convey a simple experience or information about a topic using words.	4 – Above Average Quality Presents a simple idea (e.g., a story) with some details in writing. Conveys a clear idea.	5- High Quality Conveys a rich, clear main idea (e.g., tells a story) using multiple sentences with supporting details. Conveys a focused main idea.
Characters and Setting				
1- Low Quality No evidence or insufficient evidence	2- Below Average Quality Only names characters or gives their roles (e.g., *father, the teacher, my friend, dinosaur, we, Jim*) AND/OR Only names the setting (e.g., *school, the place we were at*) Setting is vague or confused.	3- Average Quality Suggestion of characterisation through brief descriptions or speech or feelings AND/OR Suggestion of setting through very brief and superficial descriptions of place and/or time.	4 – Above Average Quality Characterisation emerges through descriptions, actions, speech or the attribution of thoughts and feelings to a character AND/OR Setting emerges through description of place, time, and atmosphere.	5- High Quality Effective characterisation: details are selected to create distinct characters AND/OR Maintains a sense of setting throughout. Details are selected to create a sense of place and atmosphere.

NOTE:

Characterisation and setting are essential components of effective narrative writing. The inclusion of AND/OR recognises that different types of stories may focus on only one aspect.

– Some stories may be character-driven and the setting may be very sketchy or undeveloped.
– Other stories, which attempt to build atmosphere and suspense, may focus on setting the scene (e.g., the wild west genre) with little character detail.
– Many stories will have a balance of these two components.

Vocabulary				
1- Low Quality Makes inconsistent letter shapes; includes imitative writing or does not write at all (symbols or drawings)	2- Below Average Quality Includes a few words, but mostly simple verbs, adverbs, adjectives, or nouns; short script.	3- Average Quality Vocabulary is limited to known, safe words and may be repetitious. Relies on slang, safe, or simple words; includes general or ordinary words, sometimes incorrectly. May attempt new or challenging words but they may not fit the message.	4 – Above Average Quality Uses words that stand on their own to convey message; uses basic vocabulary correctly. May attempt a few creative word choices; uses favourite and/or safe words correctly; experiments with more sophisticated words with some success.	5- High Quality Language choice is well matched to genre. Has precise and/or vivid word choice. Shows vocabulary is expanding through. Uses everyday words well; often employs more precise and accurate words to create variety.
Cohesion				
1- Low Quality Links are missing; short script; often confusing for the reader.	2- Below Average Quality Attempts to link parts of the text (e.g., using conjunctions), but links are incorrect.	3- Average Quality Some correct links between sentences (do not penalise for poor punctuation); most referring words are accurate; reader may occasionally need to re-read and provide their own links to clarify meaning.	4 – Above Average Quality Cohesive devices are used correctly to support reader's understanding; meaning is clear and text flows well in a sustained piece of writing.	5- High Quality Uses cohesive devices correctly and deliberately to enhance reading; an extended, highly cohesive piece of writing showing continuity of ideas.
Paragraphing				
1- Low Quality No use of paragraphing; script is a block of text.	2- Below Average Quality Text includes some randomly set of paragraph (s), not focused on one consistent idea or set of like ideas.	3- Average Quality Text organised into paragraphs that are mainly focused on a single idea or set of like ideas that assist the reader in following the story.	4 – Above Average Quality Text organised into paragraphs that are well focused on a single idea or set of like ideas that assist the reader in following and understanding the story.	5- High Quality Text deliberately structured to direct the reader's attention to the idea/set of like ideas; single sentences may be used as a dramatic or final comment or for emphasis.
Sentence Structure				
1- Low Quality Has no sentences or has only sentence parts (e.g., uses disconnected words).	2- Below Average Quality Some correct formation of sentences and some meaning can be construed; most sentences contain the same basic structures; may be overuse of the conversational 'and' or 'then',	3- Average Quality Most simple and compound sentences correct and some complex sentences are correct; meaning is predominantly clear.	4 – Above Average Quality All simple and compound sentences correct and most complex sentences are correct but with little variety; meaning is clear.	5- High Quality All simple and compound sentences correct AND all complex sentences are correct; Employs multiple sentence patterns, including a variety of sentence beginnings. Conveys simple and varied sentences effectively.
Punctuation and Capitalisation				
1- Low Quality Has no punctuation present. Contains no evidence that capital letters are for a particular purpose, if used at all.	2- Below Average Quality Attempts some random punctuation. Uses upper- and lower-case letters inconsistently.	3- Average Quality Has end punctuation that is usually correct (e.g., period, question mark, exclamation mark). Has inconsistent capitalisation but shows signs of appropriate use (e.g., some starts of sentences, names, or titles).	4 – Above Average Quality Has end punctuation that is usually correct. Attempts other punctuation, sometimes correctly (e.g., commas, colons, quotation marks). Uses capitals at the beginnings of sentences and for some names and/or titles.	5- High Quality End punctuation is always correct; attempts other punctuation, recurrently correct (e.g., commas, colons, quotation marks). Uses capitals at the beginning of sentences and fairly consistently for names, titles, and/or proper noun.
Spelling				
1- Low Quality Uses letter strings (i.e., pre-phonetic) indicating gaps in knowing letter/ sound relationships; has emerging print sense.	2- Below Average Quality Attempts phonetic spelling that is mostly decodable; may include some simple words spelt correctly.	3- Average Quality Has spotty spelling of grade-level, high-frequency words; spells some high-frequency words correctly and uses phonetic spelling on less common words.	4 – Above Average Quality Shows generally correct spelling of grade-level and high-frequency words; uses phonetic spelling on less frequent words.	5- High Quality Usually spells grade-level, high-frequency words accurately; spells less frequent/ difficult words logically with some correctly spelt.

References

Ahmed, Y., Wagner, R. K., & Lopez, D. (2014). Developmental relations between reading and writing at the word, sentence, and text levels: A latent change score analysis. *Journal of Educational Psychology, 106*(2), 419. https://doi.org/10.1037/a0035692

Allan, N. P., & Lonigan, C. J. (2011). Examining the dimensionality of effortful control in preschool children and its relation to academic and socioemotional indicators. *Developmental Psychology, 47*(4), 905–915. https://doi.org/10.1037/a0023748

Allen, M. S., Iliescu, D., & Greiff, S. (2022). Single item measures in psychological science. *European Journal of Psychological Assessment, 38*, 1–5. https://doi.org/10.1027/1015-5759/a000699

Andersen, S. C., Christensen, M. V., Nielsen, H. S., Thomsen, M. K., Østerbye, T., & Rowe, M. L. (2018). How reading and writing support each other across a school year in primary school children. *Contemporary Educational Psychology, 55*, 129–138. https://doi.org/10.1016/j.cedpsych.2018.09.005

Australian Curriculum and Assessment Reporting Authority (ACARA) (2012). *Guide to understanding ICSEA*. Australia. Retrieved from http://www.saasso.asn.au/wp-content/uploads/2012/08/Guide_to_understanding_ICSEA.pdf.

Australian Curriculum and Assessment Reporting Authority (ACARA) (2016). *National assessment program – literacy and numeracy (NAPLAN): Writing*. Australia. Retrieved from https://nap.edu.au/_resources/2010_Marking_Guide.pdf.

Australian Curriculum and Assessment Reporting Authority (ACARA) (2019). *National assessment program: literacy and numeracy*. Australia. Retrieved from https://nap.edu.au/docs/default-source/default-document-library/2019-naplan-national-report.pdf.

Australian Curriculum and Assessment Reporting Authority (ACARA) (2021). *National assessment program: literacy and numeracy*. Australia. Retrieved from https://reports.acara.edu.au/NAP.

Bañales, G., Ahumada, S., Graham, S., Puente, A., Guajardo, M., & Muñoz, I. (2020). Teaching writing in grades 4–6 in urban schools in Chile: A national survey. *Reading and Writing, 33*, 2661–2696. https://doi.org/10.1007/s11145-020-10055-z

Bell, B. A., Morgan, G. B., Schoeneberger, J. A., Kromrey, J. D., & Ferron, J. M. (2014). How low can you go? An investigation of the influence of sample size and model complexity on point and interval estimates in two-level linear models. *Methodology: European Journal of Research Methods for the Behavioral and Social Sciences, 10*(1), 1. https://psycnet.apa.org/doi/10.1027/1614-2241/a000062.

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*(3), 123–141. https://doi.org/10.2307/27740364

Berninger, V. W., Abbott, R. D., Jones, J., Wolf, B. J., Gould, L., Anderson-Youngstrom, M., … Apel, K. (2006). Early development of language by hand: Composing, reading, listening, and speaking connections; three letter-writing modes; and fast mapping in spelling. *Developmental Neuropsychology, 29*(1), 61–92. https://doi.org/10.1207/s15326942dn2901_5

Berninger, V. W., & Rutberg, J. (1992). Relationship of finger function to beginning writing: Application to diagnosis of writing disabilities. *Developmental Medicine & Child Neurology, 34*, 198–215. https://doi.org/10.1111/j.1469-8749.1992.tb14993.x

Berninger, V. W., & Winn, W. D. (2006). Implications of advancements in brain research and technology for writing development, writing instruction, and educational evolution. In C. MacArthur, S. Graham, & J. Fitzgerald (Eds.), *Handbook of writing research* (pp. 96–114). New York: Guilford Press.

Bisschop, E., Morales, C., Gil, V., & Jiménez-Suárez, E. (2017). Fluency and accuracy in alphabet writing by keyboarding: A cross-sectional study in Spanish-speaking children with and without learning disabilities. *Journal of Learning Disabilities, 50*(5), 534–542. https://doi.org/10.1177/0022219416633865

Boedeker, P. (2017). Hierarchical linear modeling with maximum likelihood, restricted maximum likelihood, and fully Bayesian estimation. *Practical Assessment, Research, and Evaluation, 22*(1), 2. https://doi.org/10.7275/5vvy-8613

Bouriga, S., & Olive, T. (2021). Is typewriting more resources-demanding than handwriting in undergraduate students? *Reading and Writing, 34*(9), 2227–2255. https://doi.org/10.1007/s11145-021-10137-6

Brydges, C. R., Reid, C. L., Fox, A. M., & Anderson, M. (2012). A unitary executive function predicts intelligence in children. *Intelligence, 40*(5), 458–469. https://doi.org/10.1016/j.intell.2012.05.006

Cai, Z., Fan, X., & Du, J. (2017). Gender and attitudes toward technology use: A meta-analysis. *Computers & Education, 105*, 1–13. https://doi.org/10.1016/j.compedu.2016.11.003

Camacho, A., Alves, R. A., & Boscolo, P. (2021). Writing motivation in school: A systematic review of empirical research in the early twenty-first century. *Educational Psychology Review, 33*(1), 213–247. https://doi.org/10.1007/s10648-020-09530-4

Cameron, C. E., Kim, H., Duncan, R. J., Becker, D. R., & McClelland, M. M. (2019). Bidirectional and co-developing associations of cognitive, mathematics, and literacy skills during kindergarten. *Journal of Applied Developmental Psychology, 62*, 135–144. https://doi.org/10.1016/j.appdev.2019.02.004

Centre for Education Statistics and Evaluation (CESE) (2021). *Are writing scores from online writing tests for primary students comparable to those from paper tests?* NSW Department of Education. Retrieved from education.nsw.gov.au/cese.

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*(4), 551–564. https://doi.org/10.1348/0007099042376373

Coker, D. L., Jr, Jennings, A. S., Farley-Ripple, E., & MacArthur, C. A. (2018). When the type of practice matters: The relationship between typical writing instruction, student practice, and writing achievement in first grade. *Contemporary Educational Psychology, 54*, 235–246. https://doi.org/10.1016/j.cedpsych.2018.06.013

Common Core State Standards Initiative (CCSS). (2016). Common core state standards from English language arts & literacy in history/social studies, science, and technical subjects. Retrieved from http://www.corestandards.org/wpcontent/uploads/ELA_Standards1.pdf.

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*(2), 479–492. https://doi.org/10.1348/000709906X116768

Cordeiro, C., Castro, S. L., & Limpo, T. (2018). Examining potential sources of gender differences in writing: The role of handwriting fluency and self-efficacy beliefs. *Written Communication, 35*(4), 448–473. https://doi.org/10.1177/0741088318788843

Curran, P. J., & Bauer, D. J. (2011). The disaggregation of within-person and between-person effects in longitudinal models of change. *Annual Review of Psychology, 62*, 583–619. https://doi.org/10.1146/annurev.psych.093008.100356

Cutler, L., & Graham, S. (2008). Primary grade writing instruction: A national survey. *Journal of Educational Psychology, 100*(4), 907. https://doi.org/10.1037/a0012656

Dahlström, D., & Boström, B. (2017). Pros and Cons: Handwriting versus digital writing. *Nordic Journal of Digital Literacy, 12*(4), 143–161. https://doi.org/10.18261/issn.1891-943x-2017-04-04

de Abreu Malpique, A., Valcan, D., Pino-Pasternak, D., & Ledger, S. (2022). Teaching writing in primary education (grades 1–6) in Australia: A national survey. *Reading and Writing, 1–27*. https://doi.org/10.1007/s11145-022-10294-2

De Smedt, F., Van Keer, H., & Merchie, E. (2016). Student, teacher and class-level correlates of Flemish late elementary school children's writing performance. *Reading and Writing, 29*(5), 833–868. https://doi.org/10.1007/s11145-015-9590-z

Dinehart, L. H. (2015). Handwriting in early childhood education: Current research and future implications. *Journal of Early Childhood Literacy, 15*(1), 97–118. https://doi.org/10.1177/1468798414522825

Dockrell, J. E., Marshall, C. R., & Wyse, D. (2016). Teachers' reported practices for teaching writing in England. *Reading and Writing, 29*(3), 409–434. https://doi.org/10.1007/s11145-015-9605-9

Donica, D. K., Giroux, P., & Faust, A. (2018). Keyboarding instruction: Comparison of techniques for improved keyboarding skills in elementary students. *Journal of Occupational Therapy, Schools, & Early Intervention, 11*(4), 396–410. https://doi.org/10.1080/19411243.2018.1512067

Drijbooms, E., Groen, M. A., & Verhoeven, L. T. W. (2015). The contribution of executive functions to narrative writing in fourth grade children. *Reading & Writing, 28*(7), 989 1011. https://doi.org/10.1007/s11145-015-9558-z

Ekholm, E., Zumbrunn, S., & DeBusk-Lane, M. (2018). Clarifying an elusive construct: A systematic review of writing attitudes. *Educational Psychology Review, 30*(3), 827–856. https://doi.org/10.1007/s10648-017-9423-5

Fitzgerald, J., & Shanahan, T. (2000). Reading and writing relations and their development. *Educational Psychologist, 35*(1), 39–50. https://doi.org/10.1207/S15326985EP3501_5

Fuchs, C., & Diamantopoulos, A. (2009). Using single-item measures for construct measurement in management research: Conceptual issues and application guidelines. Retrieved from *Die Betriebswirtschaft, 69*(2), 195–210 https://www.proquest.com/scholarly-journals/using-single-item-measures-construct-measurement/docview/750491294/se-2.

Gallagher, H. A., Arshan, N., & Woodworth, K. (2017). Impact of the national writing project's college-ready writers program in high-need rural districts. *Journal of Research on Educational Effectiveness, 10*(3), 570–595. https://doi.org/10.1080/19345747.2017.1300361

Gilbert, J., & Graham, S. (2010). Teaching writing to elementary students in grades 4 to 6: A national survey. *The Elementary School Journal, 110*(4), 494–518. https://doi.org/10.1086/651193

Graham, S. (2018). A revised writer (s)-within-community model of writing. *Educational Psychologist, 53*(4), 258–279. https://doi.org/10.1080/00461520.2018.1481406

Graham, S. (2019). Changing how writing is taught. *Review of Research in Education, 43*, 277–303. https://doi.org/10.3102/0091732x18821125

Graham, S., Berninger, V., & Abbott, R. (2012). Are attitudes toward writing and reading separable constructs? A study with primary grade children. *Reading & Writing Quarterly, 28*(1), 51–69. https://doi.org/10.1080/10573569.2012.632732

Graham, S., Berninger, V. W., Abbott, R. D., Abbott, S. P., & Whitaker, D. (1997). Role of mechanics in composing of elementary school students: A new methodological approach. *Journal of Educational Psychology, 89*, 170–182. https://doi.org/10.1037/0022-0663.89.1.170

Graham, S., Berninger, V., & Fan, W. (2007). The structural relationship between writing attitude and writing achievement in first and third grade students. *Contemporary Educational Psychology, 32*(3), 516–536. https://doi.org/10.1016/j.cedpsych.2007.01.002

Graham, S., Bollinger, A., Olson, C. B., D'Aoust, C., MacArthur, C., McCutchen, D., & Olinghouse, N. (2012b). Teaching elementary school students to be effective writers: A practice guide. NCEE 2012-4058. *What Works Clearinghouse*. Retrieved from https://ies.ed.gov/ncee/wwc/Docs/practiceguide/writing_pg_062612.pdf.

Graham, S., & Hebert, M. (2011). Writing to read: A meta-analysis of the impact of writing and writing instruction on reading. *Harvard Educational Review, 81*(4), 710–744. https://doi.org/10.17763/haer.81.4.t2k0m13756113566

Graham, S., Hebert, M., Paige Sandbank, M., & Harris, K. R. (2016). Assessing the writing achievement of young struggling writers: Application of generalizability theory. *Learning Disability Quarterly, 39*(2), 72–82. https://doi.org/10.1177/0731948714555019

Graham, S., McKeown, D., Kiuhara, S., & Harris, K. R. (2012c). A meta-analysis of writing instruction for students in the elementary grades. *Journal of Educational Psychology, 104*(4), 879–896. https://doi.org/10.1037/a0029185

Graham, S., & Perin, D. (2007). A meta-analysis of writing instruction for adolescent students. *Journal of Educational Psychology, 99*(3), 445–476. https://doi.org/10.1037/0022-0663.99.3.445

Graham, S., & Santangelo, T. (2014). Does spelling instruction make students better spellers, readers, and writers? A meta-analytic review. *Reading and Writing, 27*(9), 1703–1743. https://doi.org/10.1007/s11145-014-9517-0

Harris, K. R., Kim, Y. S., Yim, S., Camping, A., & Graham, S. (2023). Yes, they can: Developing transcription skills and oral language in tandem with SRSD instruction on close reading of science text to write informative essays at grades 1 and 2. *Contemporary Educational Psychology, 73*, Article 102150. https://doi.org/10.1016/j.cedpsych.2023.102150

Hartley, J. (1991). Psychology, writing and computers: A review of research. *Visible Language, 25*(4), 339.

Hayes, J. R. (1996). A new framework for understanding cognition and affect in writing. In C. M. Levy, & S. Ransdell (Eds.), *The science of writing: Theories, methods, individual differences, and applications* (pp. 1–27). Mahwah, NJ: Erlbaum.

Heisig, J. P., & Schaeffer, M. (2019). Why you should always include a random slope for the lower-level variable involved in a cross-level interaction. *European Sociological Review, 35*(2), 258–279. https://doi.org/10.1093/esr/jcy053

Hull, G., & Schultz, K. (2001). Literacy and learning out of school: A review of theory and research. *Review of Educational Research, 71*, 575–611. https://www.jstor.org/stable/3516099.

Jackson, T. H., & Berg, D. (1986). Elementary keyboarding-Is it important? *Computing Teacher, 13*(6), 70–71. https://www.learntechlib.org/p/169957/.

Jiménez, J. E., & Hernández-Cabrera, J. A. (2019). Transcription skills and written composition in Spanish beginning writers: Pen and keyboard modes. *Reading and Writing, 32*(7), 1847–1879. https://doi.org/10.1007/s11145-018-9928-4

Kear, D. J., Coffman, G. A., McKenna, M. C., & Ambrosio, A. L. (2000). Measuring attitude toward writing: A new tool for teachers. *The Reading Teacher, 54*(1), 10–23. https://www.jstor.org/stable/20204872.

Kellogg, R. T. (1996). A model of working memory in writing. In M. Levy, & S. Ransdell (Eds.), *The science of writing: Theories, methods, individual differences, and applications* (pp. 57–71). Mahwah, NJ: Erlbaum.

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*(2), 570–601. https://doi.org/10.3102/0034654315619491

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, 27*, 1163–1188. https://doi.org/10.1007/s11145-013-9480-1

Kim, Y. S., Al Otaiba, S., Sidler, J. F., & Greulich, L. (2013). Language, literacy, attentional behav- iors, and instructional quality predictors of written composition for first graders. *Early Childhood Research Quarterly, 28*, 461–469. https://doi.org/10.1016/j.ecresq.2013.01.001

Knudson, R. E. (1992). Development and application of a writing attitude survey for grades 1 to 3. *Psychological Reports, 70*(3), 711–720. https://doi.org/10.2466/pr0.1992.70.3.711

Kreft, I. G., & De Leeuw, J. (1998). *Introducing multilevel modeling*. Thousan Oaks, CA: Sage.

Lee, J. (2013). Can writing attitudes and learning behavior overcome gender difference in writing? Evidence from NAEP. *Written Communication, 30*(2), 164–193. https://doi.org/10.1177/0741088313480313

Leppänen, U., Aunola, K., & Nurmi, J. E. (2005). Beginning readers' reading performance and reading habits. *Journal of Research in Reading, 28*(4), 383–399. https://doi.org/10.1111/j.1467-9817.2005.00281.x

Li, X., Chu, S. K., & Ki, W. W. (2014). The effects of a wiki-based collaborative process writing pedagogy on writing ability and attitudes among upper primary school students in Mainland China. *Computers & Education, 77*, 151–169. https://doi.org/10.1016/j.compedu.2014.04.019

Limpo, T. & Olive, T. (Eds.). (2021). *Executive functions and writing* (First ed.). Oxford University Press.

Logan, S., & Johnston, R. (2010). Investigating gender differences in reading. *Educational Review, 62*(2), 175–187. https://doi.org/10.1080/00131911003637006

Maas, C. J., & Hox, J. J. (2004). Robustness issues in multilevel regression analysis. *Statistica Neerlandica, 58*(2), 127–137. https://doi.org/10.1046/j.0039-0402.2003.00252.x

Malpique, A. A., Pino-Pasternak, D., & Valcan, D. (2017). Handwriting automaticity and writing instruction in Australian kindergarten: An exploratory study. *Reading and Writing, 30*(8), 1789–1812. https://doi.org/10.1007/s11145-017-9753-1

Malpique, A. A., Pino-Pasternak, D., & Roberto, M. S. (2020). Writing and reading performance in Year 1 Australian classrooms: Associations with handwriting automaticity and writing instruction. *Reading and Writing, 33*(3), 783–805. https://doi.org/10.1007/s11145-019-09994-z

Malpique, A., Pino-Pasternak, D., Ledger, S., Valcan, D., & Asil, M. (2023). The effects of automaticity in paper and keyboard-based text composing: An exploratory study [Manuscript submitted for publication].

Man, K., Schumacker, R., Morell, M., & Wang, Y. (2022). Effects of compounded nonnormality of residuals in hierarchical linear modeling. *Educational and Psychological Measurement, 82*(2), 330–355. https://doi.org/10.1177/00131644211010234

McClelland, M. M., Cameron, C. E., Connor, C. M., Farris, C. L., Jewkes, A. M., & Morrison, F. J. (2007). Links between behavioral regulation and preschoolers' literacy, vocabulary, and math skills. *Developmental Psychology, 43*(4), 947–959. https://doi.org/10.1037/0012-1649.43.4.947

McClelland, M. M., & Cameron, C. E. (2012). Self-regulation in early childhood: Improving conceptual clarity and developing ecologically valid measures. *Child Development Perspectives, 6*(2), 136–142. https://doi.org/10.1111/j.1750-8606.2011.00191.x

McClelland, M. M., Cameron, C. E., Duncan, R., Bowles, R. P., Acock, A. C., Miao, A., & Pratt, M. E. (2014). Predictors of early growth in academic achievement: The head-toes-knees-shoulders task. *Frontiers in Psychology, 5*, 599. https://doi.org/10.3389/fpsyg.2014.00599

McCutchen, D. (1996). A capacity theory of writing: Working memory in composition. *Educational Psychology Review, 8*(3), 299–325. https://doi.org/10.1007/BF01464076

McGrail, E., & Davis, A. (2011). The influence of classroom blogging on elementary student writing. *Journal of Research in Childhood Education, 25*(4), 415–437. https://doi.org/10.1080/02568543.2011.605205

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex "Frontal lobe" tasks: A latent variable analysis. *Cognitive Psychology, 41*(1), 49–100. https://doi.org/10.1006/cogp.1999.0734

Newsom, J. (2017). Centering in Multilevel Regression. Retrieved from http://web.pdx.edu/~newsomj/mlrclass/ho_centering.pdf.

Northwest Regional Educational Laboratory (NREL) (2011). *6 +1 Trait® Writing*. Retrieved from http://educationnorthwest.org/traits.

Pajares, F. (2003). Self-efficacy beliefs, motivation, and achievement in writing: A review of the literature. *Reading & Writing Quarterly, 19*(2), 139–158. https://doi.org/10.1080/10573560308222

Pajares, F., Miller, M. D., & Johnson, M. J. (1999). Gender differences in writing self-beliefs of elementary school students. *Journal of Educational Psychology, 91*(1), 50. https://psycnet.apa.org/doi/10.1037/0022-0663.91.1.50.

Pelling, N., & Burton, L. (2017). *The elements of applied psychological practice in Australia: Preparing for the national psychology examination*. Psychology Press.

Poole, D. M., & Preciado, M. K. (2016). Touch typing instruction: Elementary teachers' beliefs and practices. *Computers & Education, 102*, 1–14. https://doi.org/10.1016/j.compedu.2016.06.008

Ponitz, C. C., McClelland, M. M., Jewkes, A. M., Connor, C. M., Farris, C. L., & Morrison, F. J. (2008). Touch your toes! Developing a direct measure of behavioral regulation in early childhood. *Early Childhood Research Quarterly, 23*, 141–158. https://doi.org/10.1016/j.ecresq.2007.01.004

Ponitz, C. C., McClelland, M. M., Matthews, J. S., & Morrison, F. J. (2009). A structured observation of behavioral self-regulation and its contribution to kindergarten outcomes. *Developmental Psychology, 45*(3), 605–619.

Preminger, F., Weiss, P. L. T., & Weintraub, N. (2004). Predicting occupational performance: Handwriting versus keyboarding. *American Journal of Occupational Therapy, 58*(2), 193–201. https://doi.org/10.5014/ajot.58.2.193

Pruden, M., Kerkhoff, S. N., Spires, H. A., & Lester, J. (2017). Enhancing writing achievement through a digital learning environment: Case studies of three struggling adolescent male writers. *Reading & Writing Quarterly, 33*(1), 1–19. https://doi.org/10.1080/10573569.2015.1059780

Puranik, C. S., Al Otaiba, S., Sidler, J. F., & Greulich, L. (2014). Exploring the amount and type of writing instruction during language arts instruction in kindergarten classrooms. *Reading and Writing, 27*, 213–236. https://doi.org/10.1007/s11145-013-9441-8

Puranik, C. S., Boss, E., & Wanless, S. (2019). Relations between self-regulation and early writing: Domain specific or task dependent? *Early Childhood Research Quarterly, 46* (228), 239. https://doi.org/10.1016/j.ecresq.2018.02.006

Raudenbush, S. W., & Bryk, A. S. (2002). *Hierarchical linear models: Applications and data analysis methods* (2nd ed.). Newbury Park, CA: Sage.

Raudenbush, S. W., Bryk, A. S., Cheong, Y. F., Congdon, R. T., & du Toit, M. (2011). *HLM 7: Hierarchical linear and nonlinear modeling*. Chicago, IL: Scientific Software International.

Reilly, D., Neumann, D. L., & Andrews, G. (2019). Gender differences in reading and writing achievement: Evidence from the National Assessment of Educational Progress (NAEP). *American Psychologist, 74*(4), 445. https://psycnet.apa.org/doi/10.1037/amp0000356.

Reutzel, P., Mohr, K. A., & Jones, C. D. (2019). Exploring the relationship between letter recognition and handwriting in early literacy development. *Journal of Early Childhood Literacy, 19*(3), 349–374. https://doi.org/10.1177/1468798417728099

Reynolds, M. R., Scheiber, C., Hajovsky, D. B., Schwartz, B., & Kaufman, A. S. (2015). Gender differences in academic achievement: Is writing an exception to the gender similarities hypothesis? *The Journal of Genetic Psychology, 176*(4), 211–234. https://doi.org/10.1080/00221325.2015.1036833

Rocha, R. S., Castro, S. L., & Limpo, T. (2022). The role of transcription and executive functions in writing: A longitudinal study in the transition from primary to intermediate grades. *Reading & Writing, 35*(8), 1911–1932. https://doi.org/10.1007/s11145-022-10256-8

Rogers, L. A., & Graham, S. (2008). A meta-analysis of single subject design writing intervention research. *Journal of Educational Psychology, 100*(4), 879. https://psycnet.apa.org/doi/10.1037/0022-0663.100.4.879.

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*(1), 37. https://psycnet.apa.org/doi/10.1037/a0013462.

Santangelo, T., & Graham, S. (2016). A comprehensive meta-analysis of handwriting instruction. *Educational Psychology Review, 28*(2), 225–265. https://doi.org/10.1007/s10648-015-9335-1

School Curriculum and Standards Authority (SCSA). (2016). English-Scope and sequence P–6. Retrieved from https://k10outline.scsa.wa.edu.au/home/teaching/curriculum-browser/english-v8/overview/English_P-10_Scope-and-Sequence_Phase_1_March_2016.PDF.

Schmitt, S. A., Geldhof, G. J., Purpura, D. J., Duncan, R., & McClelland, M. M. (2017). Examining the relations between executive function, math, and literacy during the transition to kindergarten: A multi-analytic approach. *Journal of Educational Psychology, 109*(8), 1120–1140. https://doi.org/10.1037/edu0000193

Shanahan, T., & Lomax, R. G. (1986). An analysis and comparison of theoretical models of the reading–writing relationship. *Journal of Educational Psychology, 78*(2), 116. https://psycnet.apa.org/doi/10.1037/0022-0663.78.2.116.

Shorter, L. L. (2001). *Keyboarding versus handwriting: Effects on the composition fluency and composition quality of third grade students*. University of South Alabama. Unpublished doctoral dissertation.

Skar, G. B., Lei, P. W., Graham, S., Aasen, A. J., Johansen, M. B., & Kvistad, A. H. (2022). Handwriting fluency and the quality of primary grade students' writing. *Reading and Writing, 35*(2), 509–538. https://doi.org/10.1007/s11145-021-10185-y

Siddiq, F., & Scherer, R. (2019). Is there a gender gap? A meta-analysis of the gender differences in students' ICT literacy. *Educational Research Review, 27*, 205–217. https://doi.org/10.1016/j.edurev.2019.03.007

Spear, M. G. (1989). Differences between the written work of boys and girls. *British Educational Research Journal, 15*(3), 271–277. https://doi.org/10.1080/0141192890150304

Thomas, D. P. (2020). Rapid decline and gender disparities in the NAPLAN writing data. *The Australian Educational Researcher, 47*(5), 777–796. https://doi.org/10.1007/s13384-019-00366-8

Troia, G. A., Wang, H., & Lawrence, F. R. (2022). Latent profiles of writing-related skills, knowledge, and motivation for elementary students and their relations to writing performance across multiple genres. *Contemporary Educational Psychology, 71*, Article 102100. https://doi.org/10.1016/j.cedpsych.2022.102100

Valcan, D. S., Davis, H. L., Pino-Pasternak, D., & Malpique, A. A. (2020). Executive functioning as a predictor of children's mathematics, reading and writing. *Journal of Applied Developmental Psychology, 70*, Article 101196. https://doi.org/10.1016/j.appdev.2020.101196

Valcan, D. S., Malpique, A., Pino-Pasternak, D., Asil, M. & Teo, T. (2023b). The contributions of executive functioning to handwritten and keyboarded composition in Year 2 [Manuscript submitted for publication].

Vekiri, I., & Chronaki, A. (2008). Gender issues in technology use: Perceived social support, computer self-efficacy and value beliefs, and computer use beyond school. *Computers & Education, 51*(3), 1392–1404. https://doi.org/10.1016/j.compedu.2008.01.003

Veiga-Simão, A. M., Malpique, A. A., Frison, L. M. B., & Marques, A. (2016). Teaching writing to middle school students in Portugal and in Brazil: An exploratory study. *Reading and Writing, 29*(5), 955–979. https://doi.org/10.1007/s11145-015-9606-8

Wyatt-Smith, C., Jackson, C., Borooah, V., & Whalley, K. (2018). Summary of the research report of the Australian writing survey. Retrieved from *Institute for Learning Sciences & Teacher Education.* https://www.educationstandards.nsw.edu.au/wps/wcm/connect/e61c5e7e-d553-4a33-ab0d-7297c2709302/summary-report-of-the-australian-writing-survey.pdf?MOD=AJPERES&CVID=.

Wechsler, D. (2016). *Wechsler Individual Achievement Test-Australian and New Zealand Standardised (WIAT-III A&NZ)*. Melbourne: Pearson Clinical Australia.

Weigelt-Marom, H., & Weintraub, N. (2018). Keyboarding versus handwriting speed of higher education students with and without learning disabilities: Does touch-typing assist in narrowing the gap? *Computers & Education, 117*, 132–140. https://doi.org/10.1016/j.compedu.2017.10.008

Wolbers, K. A., Dostal, H. M., Skerrit, P., & Stephenson, B. (2017). The impact of three years of professional development on knowledge and implementation. *The Journal of Educational Research, 110*(1), 61–71. https://doi.org/10.1080/00220671.2015.1039112

Wollscheid, S., Sjaastad, J., & Tømte, C. (2016). The impact of digital devices vs. Pen(cil) and paper on primary school students' writing skills–A research review. *Computers & Education, 95*, 19–35. https://doi.org/10.1016/j.compedu.2015.12.001

Yang, Y., Tam, F., Graham, S. J., Sun, G., Li, J., Gu, C., … Zuo, Z. (2020). Men and women differ in the neural basis of handwriting. *Human Brain Mapping, 41*(10), 2642–2655. https://doi.org/10.1002/hbm.24968