Reading and Writing
https://doi.org/10.1007/s11145-023-10476-6

Cross-sectional examination of the proficiency of year 1 and year 2 children's alphabet-letter-writing skills

Kathryn Mathwin[1] · **Christine Chapparo**[1] · **Julianne Challita**[1] · **Joanne Hinitt**[1]

Accepted: 8 August 2023

Abstract

The objective for beginning writers is to learn how to generate alphabet-letters which are recognisable and easy to read. This study investigated the accuracy of Year 1 and 2 children's alphabet-letter-writing by evaluating their alphabet and orthographic knowledge, following evidence which identifies these skills as important for correctly representing the Latin alphabet-letters in written form. 408 typical children from the first two years of formal schooling were recruited from eight Western Australian schools and asked to write the twenty-six-lowercase alphabet-letters under three different writing conditions: from memory; the initial sounds of words; and copying. Performance was measured using the Perceive, Recall, Plan and Perform (PRPP) System of Task Analysis (Stage One). Analyses revealed the mean average number of the 26- lowercase alphabet-letters correctly written from memory was 8.17 (Year 1) and 12.76 (Year 2). Mean averages were similar across the three writing conditions. Comparative analysis showed children in Year 2 were significantly better than Year 1 children at recalling the alphabet-sequence, sound-letter-translation, and retrieving the letter-shape, letter-case, and letter-orientation. No significant difference was found in name-to-letter translation, letter-formation, or letter-placement skills. The results highlighted that many typical Year 1 and 2 children have difficulty accurately generating all 26- lowercase alphabet-letters. The findings suggested that the way early writers learn to form and place an alphabet-letter, whether it is accurate or not, is how they continue to write the alphabet-letter through their early school journey. Considerations for evaluation and instruction of alphabet-letter-writing are discussed.

Keywords Children · Handwriting · Alphabet-letter-writing · Curriculum

✉ Kathryn Mathwin
kpmathwin@westnet.com.au

[1] Department of Occupational Therapy, Faculty of Medicine and Health, The University of Sydney, Sydney, Australia

Published online: 29 September 2023

Awareness of challenges which inhibit children's mastery of accurate alphabet-letter-writing is important for understanding the handwriting development and learning needs of beginning writers. This information is relevant to handwriting instruction offered by teachers and specialists, such as occupational therapists, who assist children challenged with handwriting. Currently, there are gaps in knowledge about handwriting milestones in the early years of school and their development. This paper examines the performance accuracy of typical children in the first two years of formal schooling when writing the 26-lowercase alphabet-letters during three writing tasks required across the curriculum: writing the alphabet from memory; from the initial sounds from words; and copying the alphabet. The findings contribute to the evaluation and instruction of alphabet-letter-writing.

The place of handwriting in schools

Despite the increasing prevalence of technology in schools, workplaces, and homes, mastering the skill of handwriting remains an important academic task for all school students. Research has shown that both handwriting and keyboarding offer benefits to young learners (Wollscheid et al., 2016), with recent studies on beginning writers finding that neither method is superior to the other (Duiser et al., 2022; Spilling et al., 2023). As the long-term impact of not teaching children how to handwrite has yet to be fully examined (Mackenzie & Spokes, 2018) and with no clear advantage to keyboarding, the teaching of handwriting remains a common practice worldwide (Collette et al., 2017; Malpique et al., 2020; Medwell & Wray, 2019). Handwriting continues to play a necessary role at all levels of education, including high school (Doug, 2019; Graham, 2019) and tertiary studies (The University of Sydney, 2023; University of Oxford, 2023), as students are required to handwrite some or all their exams. There is growing recognition of the value of handwritten exams for older students, particularly as artificial software advances and the potential for it to be misused in students' written assessments emerges (Heid, 2022). To ensure students' achievement of functional handwriting skills for their academic journey, gaining a greater understanding of early writers' handwriting development is essential.

Learning to write the alphabet-letters accurately and automatically

When children are learning how to write the alphabet-letters, the purpose is for them to generate letters that are recognisable to others familiar with the script (Treiman & Kessler, 2014). This requires a certain level of accuracy, or legibility, which is a significant contributor for readable handwriting (Fogel et al., 2022; Graham et al., 2006). Steps for accurate and timely construction of each alphabet symbol have been identified (Stefansson & Karlsdottir, 2003). For Latin alphabet-letters, this involves sequencing strokes to allow for efficient left-to-right movements (New South Wales Department of Education and Training, 1987), ensuring that each letter has a distinct shape (Longcamp et al., 2005), and that the strokes are joined following specific rules to avoid confusion between visually similar letters (such as 'r' and 'v') (Ritchey,

2008). Accurate handwriting also requires knowledge of the correct case, size, orientation, and placement of each letter (Graham et al., 2001). Any errors in these letter features, such as capital letters mid-word, incorrect height of letters, retracing or overwriting letters (Barnett et al., 2018; Graham et al., 2008), cause the reader to pause to decipher the word which impacts the flow of word recognition and reading (Perea, 2015).

Research has demonstrated that as students advance through their academic journey, legible handwriting is linked to better grades in comparison to those with less legible handwriting (Greifeneder et al., 2012). For instance, legibility plays a crucial role in the final year examinations of high school students, as illegible handwriting can lead to a loss of marks (Hiatt, 2021). Therefore, children must not only know how to generate alphabet-letters which meet the rules of the English language print requirements (accuracy) (Puranik & Lonigan, 2014), but also in a manner which allows effortless word recognition by the reader (readability) (Treiman & Kessler, 2014).

Handwriting proficiency includes the ability to write alphabet-letters accurately, easily, and with speed (Christensen, 2005). This skill is known as handwriting automaticity and is when children can generate alphabet-letters almost unconsciously without compromising legibility (Kim et al., 2018). Automatically generating alphabet-letters is considered to free up cognitive resources that would otherwise be spent on the mechanics of writing, allowing for greater focus on higher-order processes like sentence construction and revision (McCutchen, 2000). Proficient alphabet-letter-writing has been found to facilitate recognition of alphabet-letters (Longcamp et al., 2005), improved reading (Khoury-Metanis & Khateb, 2022; Malpique et al., 2020); spelling (Kim et al., 2014; Rodríguez & Villarroel, 2017), and competency in written text (Christensen, 2005; Skar et al., 2022). This study aimed to examine the accuracy, rather than the automaticity, of alphabet-letter-writing of children in their first two years of formal schooling.

Handwriting expectations and milestones of early writers

Research results are mixed about when the milestones of accurate and automatic alphabet-letter-writing are attained. Some findings suggest that children acquire handwriting skills at the beginning of primary school and plateaus before mid-Grade 2 (Gosse et al., 2021; Karlsdottir & Stefansson, 2002). However, other studies found that with regular teaching and practice, children in Year 2 continue to make improvement in their handwriting abilities which stabilised in the middle of Year 3 (Duiser et al., 2020; Overvelde & Hulstijn, 2011). The variability in the type of handwriting instruction the children received at school (Kim et al., 2014), children's age, and the variety of handwriting measures used to assess children's handwriting may have contributed to the differing results (Duiser et al., 2020).

Evaluation of children's alphabet-letter-writing

This research was carried out in Western Australia. The Western Australian curriculum stipulates that Year 1 students should write using unjoined upper and lowercase alphabet-letters (School Curriculum and Standards Authority, 2021). By Year 2, students' handwriting should be legible and show growing fluency. An explanation of what constitutes a legibly formed alphabet-letter was not found in the handwriting guidelines. In Western Australia, teachers rely on subjective evaluations rather than formal testing to assess children's handwriting proficiency (Mariano et al., 2022). This is similar to other Australian states (Mackenzie, 2021) and English-speaking countries such as England (Medwell & Wray, 2019) and the United States (Collette et al., 2017; Graham et al., 2008) who also report that formal school testing of children's handwriting is not common practice. The absence of formal evaluation may relate to the lack of consensus about how handwriting should be measured (Barnett et al., 2018; Puranik & Lonigan, 2011).

Although there is no general agreement on how to measure children's handwriting, evaluation tools have been developed to determine children's handwriting proficiency and to identify those at-risk of handwriting difficulties (Diekema et al., 1998; Roston et al., 2008). However, each measurement tool varies in the focus and assessment methods used. For example, some assessments evaluate the global legibility (readability) of written alphabet-letters (Barnett et al., 2018), while others measure different features of specific legibility components such as letter-formation, size, and letter-placement (Diekema et al., 1998; Overvelde & Hulstijn, 2011). Assessments differ in the writing surfaces and scoring systems used and employ different writing tasks such as copying, dictation or from memory (Chrisman et al., 2013; Roston et al., 2008). Each variant evaluates different features of children's alphabet-letter-writing knowledge, use and skills (Duiser et al., 2020). For example, copying letters does not have memory requirements for sound-to-letter translation, retrieval of the visual-symbol or letter-placement, as this information can be gathered from the visual model (Graham et al., 2006; Mathwin et al., 2022). The absence of objective, consensual evaluation parameters for measuring accuracy of children's alphabet-letter-writing across curricula writing tasks is problematic for the creation of a coherent portrait of early childhood handwriting development.

Classroom alphabet-letter-writing instruction

Handwriting is a learned skill, requiring specific teaching (Ritchey, 2008). Recommended handwriting instruction includes providing verbal and visual demonstrations and opportunities for students to practice (Santangelo & Graham, 2016). Workbooks are commonly used in classrooms (Mackenzie, 2021), which use tracing, copying, faded prompts, and visual cues like starting dots and directional arrows. Such features are considered to help children develop the correct movement sequence and spatial parameters for writing letters (Graham et al., 2006). Training children in self-evaluation is also advised (Santangelo & Graham, 2016) which may include identifying errors (Mathwin et al., 2022), directing children to correct inaccurately formed

alphabet-letters, or identify their best written letters (Graham et al., 2008; Vander Hart et al., 2010).

However, Australian (Malpique et al., 2020; McLean & Griffiths, 2022), and international (Håland et al., 2019; Vander Hart et al., 2010) research has found that not all early learners receive the recommended classroom handwriting instruction. Examination of in-class handwriting instruction has found that in comparison to the recommended guidelines, instructional techniques are not consistently emphasised and adequate time and opportunities for children to practise handwriting are not provided (Graham et al., 2008; Malpique et al., 2020; Vander Hart et al., 2010). Challenges preventing teachers deliver the recommended handwriting instruction include: pressures to meet curriculum requirements; inadequate university teacher training in effective handwriting instruction methods; the expectation to provide both handwriting and keyboarding training (de Abreu Malpique et al., 2022; Graham et al., 2008; Wyatt-Smith et al., 2018) and handwriting not being highly prioritised (Doug, 2019).

Current study

This study aimed to evaluate the accuracy of Years 1 and Year 2 children's alphabet-letter-writing. The measurement tool used in this study was based on evidence identifying the importance of alphabet and orthographic knowledge in establishing proficiency in children's alphabet-letter-writing. Alphabet knowledge is required as children need to recognise letter-shapes (Molfese et al., 2006; Puranik et al., 2011), know the letter-names (Khoury-Metanis & Khateb, 2022; Rodríguez & Villarroel, 2017) and the meaning behind their symbology (Puranik et al., 2014) to write them. Orthographic knowledge is necessary as it encompasses the rules a particular language uses to define a correctly represented visual-symbol (writing alphabet-letters) (Abbott & Berninger, 1993; Puranik & Apel, 2010) or strings of visual-symbols (spelling and reading) (Apel et al., 2018; Ouellette & Sénéchal, 2008).

Orthographic knowledge is thought to play a critical role in the development of alphabet-letter-writing legibility when children are first learning to write (Weintraub & Graham, 2000). However, orthographic knowledge is more commonly related to words than alphabet-letters, even though alphabet-letters have been described as the smallest orthographic unit (Jiménez, 2017) and alphabet-letter-writing as an early orthographic skill (Puranik & Apel, 2010). Orthographic knowledge for words is described as having two levels; the sub-lexical level which defines the rules and patterns within words, and a lexical level which involves the retrieval and imagery of whole or parts of words (Apel et al., 2018). The lexical level is important for fluent reading and spelling so words can be produced (for writing) or recognised (for reading) with little cognitive effort (Ouellette & Sénéchal, 2008).

In the absence of literature applying orthographic knowledge to assessment of alphabet-letter-writing, the assumption underlying this study was that retrieval of alphabet-letters for the purpose of letter-writing is similar to the way orthographic knowledge is retrieved for words. Therefore, when writing alphabet-letters, children require an understanding of the rules of the internal structure of each letter which informs the correct way of representing alphabet-symbols on paper (as with sub-

lexical orthographic knowledge). These rules include: correct letter-formation; legibility-rules (stroke-angles, stroke-ratio, stroke-orientation, stroke-connections); and letter-placement. It was hypothesised that once children can create clear mental representations of alphabet-letters, as with lexical orthographic knowledge for words, they can effortlessly recognise, retrieve, and write them.

Some of the orthographic features measured in this study are like the legibility components assessed in other handwriting assessments (Diekema et al., 1998; Graham et al., 2006). However, in this study it was posited that the alphabet and orthographic rules define one correct way (depending on the font used) to represent each alphabet-letter in written form. Therefore, 100% criteria (ceiling score) in alphabet and orthographic knowledge indicated that a child had obtained and could implement all necessary information to correctly generate all 26-lowercase alphabet-letters. Alternatively, alphabet-symbols written with errors thereby breaking an alphabet or orthographic rule (of alphabet-letters) suggested that the child had inadequate or inaccurate alphabet and/or orthographic knowledge (Weintraub & Graham, 2000) impacting their ability to correctly translate and transcribe alphabet-letters. It was with these assumptions the measurement tool used in this study determined the alphabet-letter-writing abilities of typical children in their first two years of formal schooling across three curriculum-based writing tasks: writing the alphabet-letters from memory; initial sound in words; and copying.

Research questions

This study was guided by the following three research questions:

1. How accurately do children who are in their first two years of formal schooling perform when completing three alphabet-letter-writing tasks: writing alphabet-letters from memory (AFM); writing alphabet-letters from initial sounds of words (AIS); and writing alphabet-letters from copying (CA) as measured by the Perceive, Recall, Plan, and Perform (PRPP) System of Task Analysis (Stage One)?
2. What is children's performance in terms of alphabet and orthographic knowledge across three different alphabet-letter-writing tasks?
3. How does the performance of children in the first year of formal schooling compare to the performance of children in the second year of formal schooling when writing the 26-lowercase alphabet-letters?

Methods

Study design

This study employed a cross-sectional, descriptive, quantitative research design which explored early learners' alphabet-letter-writing abilities. Data were collected from a sample of children who attended mainstream schooling. These data comprised handwriting assessment information based on the Perceive, Recall, Plan and Per-

form (PRPP) System of Task Analysis (Stage One). Data were then analysed using descriptive and comparative techniques to investigate and compare children's alphabet-letter-writing skills across the two grades.

Participants

A convenience sample of schools were contacted and invited to participate in the study. Five government urban schools, one urban Anglican school, one government rural school, and one Catholic rural school agreed to partake. A requirement for inclusion of schools was that Year 1 (Y1) and Year 2 (Y2) students had used the dotted-third paper for writing (paper which provides visual cues for where letters start and end). The dotted-third paper is commonly used in Western Australian schools and was incorporated as part of the measurement tool used in this study.

Participants in this study included students in Years 1 and 2 of mainstream primary school education in Western Australia. These years are preceded by a formal preparatory year (Pre-primary for five-year-olds) in which children begin to learn foundation academic skills which include letter recognition and alphabet-letter-writing. The eligibility requirements for children to take part in the study were that: children attended a mainstream Y1 or Y2 classroom; had no known neurological diagnosis, vision, or hearing impairment which may have impacted their learning at school; and were able to converse in English (as spoken in Australia) with the researcher. The participants included 207 Y1 children (100 boys and 107 girls) with the mean age of 6 years, 5 months; and 201 Y2 children (113 boys and 88 girls) with a mean age of 7 years, 7 months.

Procedure

Ethical approval was obtained from The University of Sydney [Project No: 2019/261], the Government of Western Australian Department of Education [D21/0029448] and the Catholic Education Western Australian [RP2020/24]. Once school, teacher and parent consent were obtained, the researcher organised a time to visit the school from Term 2 to Term 4 (May – December) of the Western Australian school year. The researcher tested each child individually at a time and place recommended by the teacher. Each child was asked to complete three different alphabet-letter-writing tasks.

Task 1. writing alphabet-letters from memory (AFM)

This task measured use of alphabet-knowledge (alphabet-sequence and correlation of letter-name with the correct letter-shape) and orthographic knowledge (of alphabet-letters). Children were asked to write the alphabet in lowercase letters. Those who were uncertain about how to complete the task were prompted with the *alphabet song* and an example of a capital and lowercase letter. They were instructed, if they made a mistake, to cross the letter out and attempt the letter again. The task ceased when children could not remember any more of the alphabet-sequence or wrote more than

five random letters in the incorrect alphabet order. All generated alphabet-letters were scored, including those written in the incorrect sequence.

Task 2. writing alphabet-letters from initial sounds (AIS)

This task did not require recalling the alphabet-sequence and involved translating letter-sounds rather than letter-names. In this writing task, each letter was represented by a familiar item on a laminated sheet. Children were asked to identify the picture, the initial sound (e.g., 'd' for 'dog') and then write the corresponding letter. Children having trouble isolating the sound were given assistance, as the task was to determine alphabet-letter-writing abilities as opposed to phonetic awareness.

Task 3. writing alphabet-letters from copying (CA)

The task of copying investigated children's alphabet-letter-writing skills when not required to access alphabet and orthographic knowledge. In this task, children were provided with a visual model of the alphabet and asked to copy the lowercase letters onto the page.

The time taken to complete all three alphabet-letter-writing tasks was between 5 and 10 min.

Outcome measure

Data were collected using a procedural task analysis based on the Perceive, Recall, Plan and Perform (PRPP) System of Task Analysis (Stage One) (Chapparo & Ranka, 2014). The PRPP (Stage One) is a process-orientated, criterion-referenced assessment which employs a procedural task analysis to break down everyday tasks, such as writing the alphabet-letters, into observable and measurable steps to identify errors. Mastery of the task is determined by the percentage of steps performed without errors.

PRPP (Stage One) was selected as the outcome measure for this study for several reasons. First, at the time of conducting the study, no other handwriting assessment was found which enabled measurement of alphabet and orthographic skills related to alphabet-letter-writing. Second, as this study was investigating errors in alphabet and orthographic knowledge, an assessment tool with the capacity to break down the steps of the task into the specific subskills was required (Chapparo & Ranka, 2014). Third, subjectivity of scoring a correctly written alphabet-letter was minimised as the scoring rubric focused on explicitly defining errors. PRPP (Stage One) has been used to measure performance mastery across a range of child diagnostic groups, such as learning difficulties (Lowe & Chapparo, 2010), social competence (Challita et al., 2019), and autism (Mills et al., 2016).

As per PRPP (Stage One) administration procedures (Chapparo & Ranka, 2014), the alphabet-letter-writing tasks were measured as follows:

Alphabet-letter-writing overall mastery score

Each correctly written letter which had no alphabet or orthographic errors scored one point, yielding a maximum total accuracy score of 26 for each writing task. The total number of correctly written letters were tallied, and this raw score was converted to a percentage score reflecting level of mastery of the whole task (e.g., 4 correctly written letters out of 26/100 = 15%). Figure 1 provides an example of a completed scoring form.

Alphabet and orthographic subskills of alphabet-letter-writing

A breakdown of alphabet and orthographic skills were used to determine accuracy of the alphabet-letters written. Alphabet knowledge measured children's accuracy of matching the letter-name/letter-sound with the letter-shape. Orthographic knowledge output was broken down into three subsections: retrieving mental representations of letters (recalling visual-symbol and selecting the correct case); understanding alphabet-letter's internal structure (starting position, sequence of strokes, orientation,

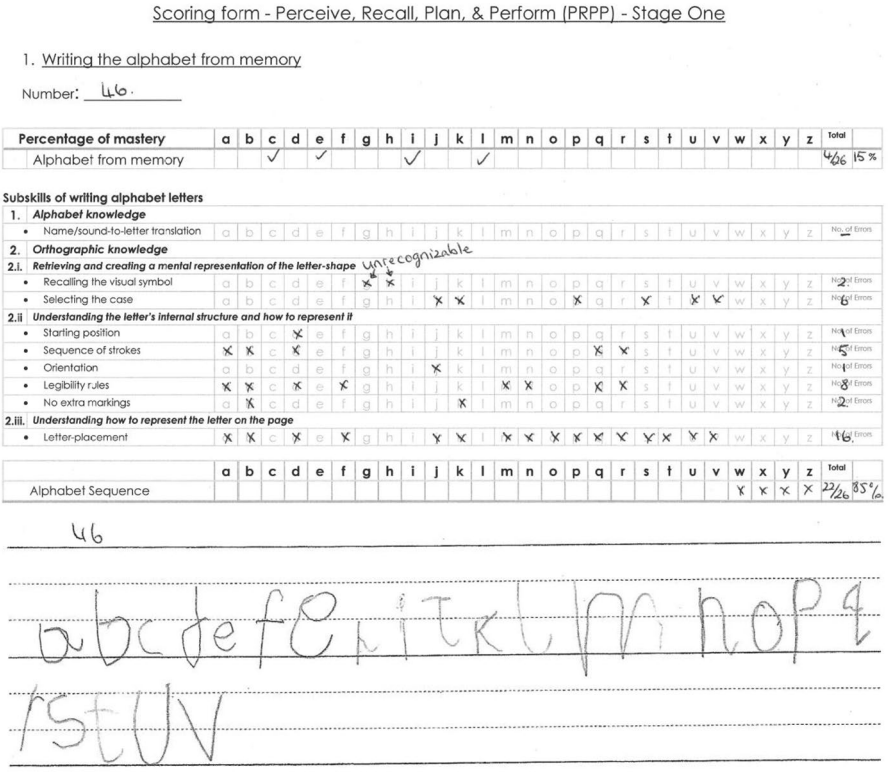


Fig. 1 Example of PRPP (stage one) scoring form for alphabet-letter-writing

legibility-rules {Appendix A}, extra markings); and rules of representing alphabet-letters on paper. Table 1 outlines representations of errors in each subskill.

If an error was observed in any subskill, the letter was scored as incorrect in the overall mastery score. The total number of errors for each subskill were recorded in the right-hand column of the scoring form (Fig. 1). These were not converted into a percentage score because under each writing condition, a child could potentially write a different number of alphabet-letters depending on their familiarity with the alphabet-sequence or name/sound-to-letter translation. This meant other subskills (e.g., sequence of strokes or legibility-rules) could not be scored. Therefore, deriving a percentage score of accuracy for each subskill would make comparing scores between children an inaccurate reflection of their overall proficiency of applying the subskills.

Several performance observations were made while the child carried out the writing task (e.g., errors with recalling the letter-shape or starting position,) as these subskills could not be determined from the surface characteristics alone. When scoring the writing samples, a protractor was used to measure stroke-angles, and a ruler to measure stroke-connection and letter-placement. The dotted-third lined paper was used as measuring points to evaluate letter-placement (as depicted in Appendix A). Letter-size was not measured in this study given that correct letter-placement on the dotted-third lines meant correct letter-size. The same scoring system was used for each alphabet-letter-writing task.

Children were required to attempt writing at least 10 alphabet-letters in any of the writing tasks for their data to be included in all statistical analyses. This benchmark was decided as nine or less alphabet-letters would not provide enough data for results of the alphabet and orthographic subskills to be comparable to the children who generated 10 or more alphabet-letters. Additionally, by including their data in the overall percentage mastery analysis and not the alphabet and orthographic subskill analysis would provide an inconsistent interpretation of the overall results.

All writing samples were collected and scored by the primary researcher.

Inter-rater and intra-rater reliability

The PRPP System of Task Analysis has demonstrated good validity and rater-reliability ranging from 0.64 to 0.99 (Nott & Chapparo, 2012). To test for the trustworthiness of measurement procedures used in this particular study, inter-rater and intra-rater reliability were examined. Interrater reliability was tested by examining three scores: the original score; and the scores derived from two experienced occupational therapists who rescored 60 randomly selected writing samples under blinded conditions. Results using Intraclass Correlation Coefficients ICC(2,1) yielded a result of 0.96 [CI: 0.94–0.98]. Intra-rater was evaluated by the primary researcher rescoring 60 (blinded) randomly selected writing samples which were compared with the original scores. ICC(2,1) was determined as 0.97 [CI: 0.97–0.99]. Both inter- and intra-rater reliability showed very good agreement demonstrating consistency and reliability in the use of this measuring tool for this study.

Table 1 Scoring of alphabet-letter-writing subskills

Subskill	Description of Errors
1. Alphabet knowledge – *Correlating the correct sound with the correct symbol*	
Name/sound-to-letter-translation	- The child says a letter-name/sound but writes the incorrect alphabet-symbol. E.g., the child said 'v' but writes a 'b', or says 's' but writes an 'x'.
2. Orthographic knowledge – Correct representation of the alphabet-symbol	
i. *Retrieving and creating a mental representation of the alphabet-letter-shape*	
Recalling the letter shape	- The child says, "I can't remember what a 'h' is?" or "What does a "u" look like?". - The child looks around the room for an image of the letter to copy - The letter written is unrecognisable. - Sits for longer than 10 s without writing the letter.
Selecting the case	- The child recalls the correct letter but the incorrect case, e.g., writes uppercase instead of a lowercase letter.
ii. *Understanding the alphabet-letter's internal structure and how to represent it*	
Starting position	- The child starts the alphabet-letter in the incorrect position.
Sequence of strokes	- Any letters that are not written in the sequence of strokes outlined by the font's guidelines taught at school.
Orientation	- The letter is reversed or orientated in the incorrect direction.
Legibility rules	- The child's letter does not comply with the legibility-rules for (Refer to Appendix A for further details) - o the angle of strokes. o how the strokes are connected . o the size and/or ratio of strokes.
No extra markings	- The child notices they made an error and attempts to correct the error by writing over the letter. - The child is unsure of the sequence of strokes so adds random markings.
iii. *Understanding where to represent the alphabet-letter on the page*	
Letter-placement	- The letter-placement is scored correct if there is a 1 mm or less gap at each measuring point on the dotted-third lines. - An error is scored if – o Two or more points of the letter do not touch the dotted-third line by 1–2 mm. o Any point of the letter does not touch a dotted-third line by 2 mm or more. - Letters are scored if two adjacent letters are touching.

Data analysis

The Statistical Package for Social Science Statistic (IBM SPSS®) Version 23 was used to analyse the data. Several statistical analyses were employed to address the three research questions.

Research question 1: performance of Y1 and Y2 alphabet-letter-writing

Descriptive statistics were used to address the first research question in exploring how accurately children perform alphabet-letter-writing across the three writing conditions. First, the raw scores of the number of accurately written alphabet-letters for each child, in each writing condition, were converted into a percentage score. Second, descriptive statistics were used to obtain the total raw score mean, the percentage mastery mean, and standard deviation for each writing task.

Research question 2: application of alphabet and orthographic knowledge

In addressing the second research question, descriptive statistics were used to examine the children's ability to apply alphabet and orthographic subskills required for correct alphabet-letter-writing. For each subskill, children were categorised into those who made no errors and those who made one or more errors of that particular subskill area in the alphabet-letters they generated. A percentage score was then calculated based on the number of children who made no errors (hence had no difficulty with that subskill for the alphabet-letters they wrote) and those who had difficulty.

Research question 3: comparison of Y1 and Y2 alphabet-letter-writing

Comparative analysis was then used to explore the similarities and differences between Y1 and Y2 children in writing the 26-lowercase alphabet-letters. The data were first screened for normalcy. The Shapiro-Wilk's test ($p > 0.05$) and visual inspection of histograms demonstrated the data were not normally distributed. Therefore, non-parametric Mann-Whitney U test was used to compare performance between Y1 and Y2 children based on the overall percentage mastery score for the three alphabet-letter-writing conditions. Since scoring for the alphabet and orthographic sub-skill areas is classed as categorical data, chi-square test of independence was used to compare children's performance. Statistical significance was set at $p < 0.05$.

Results

Research question 1: performance of Y1 and Y2 alphabet-letter-writing

Table 2 illustrates the overall percentage score obtained by Y1 and Y2 children when writing the 26-lowercase alphabet-letters across the different writing conditions. The mean scores for Y1 children were similar across the three writing tasks. This also

Table 2 Performance of mastery in alphabet-writing tasks

Alphabet-Writing Tasks	*M* % score (*M* raw score)		*SD*	
	Year 1	Year 2	Year 1	Year 2
Alphabet from memory	31.4 (8.2)	49.0 (12.7)	7.7	7.5
Writing initial sounds	32.3 (8.5)	49.2 (12.8)	7.6	7.0
Copying the alphabet	34.3 (8.9)	48.3 (12.6)	7.7	7.3

Note. Number of letters written correctly out of total alphabet (26 alphabet-letters)

Table 3 Descriptive statistics - alphabet and orthographic subskills of alphabet-letter-writing

	% of Children with Zero Errors from Alphabet-Letters they Generated					
Subskill	Alphabet from Memory (AFM)		Alphabet from Initial Sounds (AIS)		Copying the Alphabet (CA)	
	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2
1. Alphabet Knowledge						
Letter-Sound/Name Translation	70%	81%	59%	79%	Not required	
2. Orthographic Knowledge						
i. *Retrieving and creating a mental representation of the alphabet-letter-shape*						
Recalling the letter	69%	89%	56%	81%	Not required	
Selecting the case	39%	60%	36%	54%	48%	60%
ii. *Understanding the alphabet-letter's internal structure and how to represent it*						
Starting position	68%	73%	73%	72%	74%	74%
Sequence of strokes	22%	34%	22%	30%	22%	33%
Orientation	51%	69%	41%	74%	72%	87%
Legibility rules	10%	9%	6%	9%	4%	9%
No extra markings	49%	55%	63%	60%	55%	56%
iii. *Understanding where to represent the alphabet-letter on the page*						
Letter-placement	5%	13%	4%	10%	6%	9%

occurred for the Y2 children. On average, Y1 children correctly wrote around 8 to 9 letters out of the 26, while Y2 children accurately generated 12 to 13 letters.

Writing samples from children who were not able to attempt 10 or more letters were not included in the statistical analyses. Of the 408 children who participated in the study, in the AFM writing task, 16 Y1 and four Y2 children were not included; in AIS, three Y1 and no Y2 children; and in CA writing task, four Y1 children and no Y2 children.

Research question 2: application of alphabet and orthographic knowledge

Table 3 displays the results of the alphabet and orthographic subskills for Y1 and Y2 children. Each score represents the percentage of children who made no errors for the relevant subskill in the alphabet-letters they generated. The results revealed that all alphabet and orthographic subskills attracted some difficulty from both Y1 and Y2 children, with some subskills having greater numbers of children with correct responses than others. The subskills with the highest percentage of children who made correct responses were recalling visual symbols, converting the letter-name into the correct alphabet-letter, and the sound-to-letter translation. The Y2 group had more children who made no errors in these respective subskills than the Y1 group.

The starting position, not adding extra markings or overwriting letters, and letter-orientation (for Y2 children, not for the Y1 group) had the next highest number of children adhering to the rules. Using the correct stroke sequence and following the legibility and letter-placement rules had the lowest number of children from both year groups with correct responses.

As shown in Table 3, for some subskills, the results varied depending on the writing condition. In the alphabet knowledge subskill, a greater number of Y1 children could accurately translate and recall the visual symbol from the letter-name (AFM) than when translating from the letter-sound (AIS). In the copying condition, more Y1 children demonstrated accuracy in selecting the letter-case and correctly orientating the letters, than when required to write from memory (AFM and AIS). For Y2 children, the only notable difference in the various writing conditions was that more children could accurately orientate letters in the copying task, than in the memory tasks. Otherwise, the results for the remaining subskills showed that the percentage of Y1 children who made no errors were similar across the different writing tasks. The same pattern was observed with the Y2 students.

The results of the children's ability to remember the order of the alphabet-sequence are not displayed in Table 3. The descriptive results showed that Y2 children had a higher percentage score mean (M = 91.96% {23.91 alphabet-letters in the correct order}, SD = 4.68) than Y1 children, who scored (M = 82.31% {21.46 alphabet-letters in the correct order}, SD = 6.95).

Research question 3: comparison of Y1 and Y2 alphabet-letter-writing

The third research question investigated whether there were significant differences between Y1 and Y2 children's capacity to write alphabet-letters and apply the alphabet and orthographic subskills in different writing conditions. Table 4 displays the results of the comparative analysis.

Overall mastery of alphabet-letter-writing

The results of the Mann-Whitney *U* Test revealed that Y2 children were significantly more accurate than Y1 children in alphabet-letter-writing skills across all three writing conditions (AFM: $U = 12{,}278$, $z = -5.93$, $p < 0.001$, $r = 0.30$; AIS: $U = 13{,}679$, $z = -5.80$, $p < 0.001$, $r = 0.29$; CA: $U = 14{,}727$, $z = -0.84$, $p < 0.001$, $r = 0.24$), with *r* signifying a medium effect.

Alphabet and orthographic knowledge subskills

Table 4 shows Y2 children performed significantly better than Y1 children in various subskills, such as recalling letter-shapes from letter-names and letter-sounds, writing the correct case, and letter-orientation under all writing conditions. However, there were no significant differences between the two groups in areas such as starting position, legibility-rules, not adding extra markings, and name-to-letter translation. The difference in sequence-of-strokes and letter-placement was either insignificant or had a small effect size ($r < -0.13$) across all writing conditions.

Table 4 Comparative statistics - year 1 and year 2 children's alphabet and orthographic subskills

	Alphabet From Memory (AFM)			Alphabet from Initial Sounds (AIS)			Copying the Alphabet (CA)		
Subskill	X^2	*p*	φ	X^2	*p*	φ	X^2	*p*	φ
1. Alphabet Knowledge									
Name/ sound-to-letter	2.343	0.126	-0.08	16.775	0.001*	-0.20	Not required		
2. Orthographic Knowledge									
i. *Retrieving and creating a mental representation of the alphabet-letter-shape*									
Recalling the letter	17.573	0.001*	-0.21	27.485	0.001*	-0.26	Not required		
Selecting the case	13.301	0.001*	-0.18	11.767	0.001*	-0.17	4.876	0.027*	-0.11
ii. *Understanding the alphabet-letter's internal structure and how to represent it*									
Starting position	0.033	0.856	-0.01	0.423	0.515	0.03	0.266	0.606	0.03
Sequence of strokes	6.144	0.013*	-0.13	3.201	0.074	-0.09	5.219	0.022*	-0.11
Orientation	10.092	0.001*	-0.16	44.997	0.001*	-0.33	11.877	0.001*	-0.17
Legibility rules	0.370	0.543	0.03	1.394	0.238	-0.06	1.659	0.198	-0.06
Extra markings	0.232	0.630	-0.02	0.534	0.465	0.04	0.013	0.991	-0.01
iii. *Understanding where to represent the alphabet-letter on the page*									
Letter-placement	6.221	0.013*	-0.13	3.998	0.046*	-0.10	1.361	0.243	-0.06

*$p < 0.05$

Discussion

Accuracy of Y1 and Y2 children's alphabet-letter-writing

The first research question aimed to assess the proficiency of typical children in writing lowercase alphabet-letters during their initial two years of formal education under three different writing conditions. The results showed that, on average, Y1 children correctly wrote between eight and nine of the 26 letters, while Y2 children accurately generated 12–13 letters in all three writing conditions. As evaluated by the handwriting measure used in this study, the results suggest many Y1 and Y2 children are not meeting Western Australian school curriculum requirements (School Curriculum & Standards Authority, 2021) for correctly writing the 26-lowercase alphabet-letters. However, validating this claim is challenging since Australian school handwriting guidelines (Mackenzie, 2021) do not specifically define the quality of alphabet-letter-writing expected and there is no agreed-upon national or international standard for what constitutes accurately formed alphabet-letters (Barnett et al., 2018; Puranik & Lonigan, 2011). Additionally, comparing the handwriting accuracy of Y1 and Y2 children in this study with other studies is also difficult due to the use of different handwriting evaluation tools, writing tasks, and scoring procedures (Duiser et al., 2020; Gosse et al., 2021; Karlsdottir & Stefansson, 2002; Overvelde & Hulstijn, 2011). These results highlight the need for additional research to develop consensus on what constitutes an accurately formed alphabet-letter, and at what age such standards should be achieved. This may provide greater guidance to educators and specialists who assist children with handwriting difficulties, such as occupational

therapists, to determine whether children are meeting developmental milestones and curriculum expectations.

The second research question aimed to identify which alphabet and orthographic subskills most influenced children's ability to write the alphabet-letters correctly. The results revealed that both Y1 and Y2 children encountered difficulties in all alphabet and orthographic subskills. The subskills that most Y1 and Y2 children made errors were letter-placement, legibility-rules, and letter-formation. Almost half of the children from both year groups found it challenging to select the correct case and avoid adding extra markings or overwriting letters. Many Y1 children and some Y2 children had difficulty translating letter-sounds into the corresponding letter-symbol and recalling the letter-shape to write. Overall, the findings indicated that a majority of Y1 and Y2 children exhibited inaccurate or inadequate alphabet and orthographic knowledge (of alphabet-letters) (Weintraub & Graham, 2000). The inability to follow the alphabet and orthographic rules could impact the accurate representation of the alphabet-letters (Puranik et al., 2014; Stefansson & Karlsdottir, 2003), which could, in turn, affect the reader's ability to recognize and read their handwriting with ease (Apel et al., 2013; Perea, 2015). Further research is necessary to explore the correlation between children's alphabet and orthographic knowledge (of alphabet-letters), their ability to accurately write the alphabet-letters, and the readability of their handwritten text.

Similarity and difference between Y1 and Y2 alphabet-letter-writing

The third research question examined the performance differences between the year groups in alphabet-letter-writing and the alphabet and orthographic subskills. The results indicated Y2 children were significantly better at correctly writing the 26-lowercase alphabet-letters than Y1 in all three writing conditions. Examination of the alphabet and orthographic subskills results demonstrated Y2 children were better than Y1 in remembering the alphabet-sequence, translating and recalling alphabet-letters, case-selection, and letter-orientation. Y2 children's improved abilities in these subskills may explain why the Y2 mean for correctly written alphabet-letters was significantly greater compared to Y1 children. Conversely, the subskill results which demonstrated no or inconsistent differences between Y1 and Y2 children in the three writing conditions were: starting position; sequence of stroke; not adding extra markings; legibility-rules; and letter-placement. These results suggest that children's abilities to accurately understand the internal representation of alphabet-letters and how to form and place letters, appear not to change between Y1 and Y2. This outcome may indicate that the way children learn to generate letter-formation (other than orientation) and letter-placement in Y1 is the way they continue to form and place alphabet-letters, in most writing conditions in Y2. The children in this study appeared to develop different aspects of alphabet-letter-writing at different times during the first two years of school. This was a cross-sectional study. To better understand the emergence of early alphabet-letter-writing development, its components, and its relationship to written expression, further longitudinal studies of the same children over time are required.

Alphabet-letter-writing evaluation

Results from both year groups indicated that different aspects of children's alphabet-letter-writing knowledge were measured in the different writing tasks. First, more children, particularly from Y1, were unable to generate 10 or more alphabet-letters in the AFM task than in AIS and CA, suggesting that AFM was the more challenging writing task. This may be related to difficulties recalling the alphabet-sequence, while simultaneously translating the letter-name and recalling the letter-shape, letter-formation, and letter-placement (Rodríguez & Villarroel, 2017). Second, in AIS, the results showed that more Y1 children had difficulty with sound-to-letter translation, than with name-to-letter translation in AFM. Some Y2 children also demonstrated difficulty with both name and sound-to-letter translation. This result was unexpected considering that translating letter-sounds rather than letter-names into visual symbols is presumed to be a more common task when practising spelling (Kim et al., 2014) and identified as a requirement to ensure the correct alphabet-letter is written (Khoury-Metanis & Khateb, 2022; Ritchey, 2008). Third, in CA a higher percentage of Y1 children selected the correct-case and more Y1 and Y2 children correctly oriented their letters, than in AFM and AIS. This indicated that while some children were unable to recall this information from memory, accuracy occurred when a visual model was available.

Cumulatively, the findings provide several considerations for handwriting evaluation. The results lend support for the view that alphabet-letter-writing may reflect children's understanding of how letter-sounds/names are represented by which alphabet-symbol, rather than solely on how to produce each alphabet-letter (Abbott & Berninger, 1993; Puranik & Apel, 2010). These results provide support for the inclusion of measuring alphabet knowledge when evaluating children's alphabet-letter-writing skills (Kim et al., 2014; Molfese et al., 2006). Additionally, the outcomes raise the question of the usefulness of copying as the sole writing task for examining children's alphabet-letter-writing. The act of copying may not measure all alphabet and orthographic subskills as comprehensively as writing tasks which require children to self-generate alphabet-letters from the letter-name (as in AFM) or from the letter-sound (as in AIS) (Graham et al., 2006; Mathwin et al., 2022). Research is required to further explore these assumptions.

Alphabet-letter-writing instruction

The results of this research offer a number of insights for instruction of alphabet-letter-writing. First, based on the study results, it can be inferred that errors in the way children learn to form and position alphabet-letters in Y1, if not corrected in early learning stages, may impact how they write alphabet-letters (other than orientation) in Y2. This highlights the importance of teaching correct writing techniques at the very beginning when children learn to write letters and monitoring their letter-writing skills until an expected level of accuracy is achieved. Then, as children practice handwriting, they practice writing the alphabet-letters correctly to set them on a path for legible and readable handwriting.

Second, the study proposed achieving a ceiling score of 100% on the measuring tool used in this study would indicate that children had acquired the alphabet and orthographic knowledge necessary to enable writing alphabet-letters accurately. Further research could examine the impact of training beginner writers in these subskills, including what constitutes a violation of an alphabet or orthographic rule. This training could enhance children's self-evaluation skills (Santangelo & Graham, 2016) to recognise and fix errors, leading to mastery of the correct methods for alphabet-letter-writing. Practising alphabet-letter-writing would require writing from memory rather than copying to facilitate the development of retrieval routes for alphabet and orthographic knowledge (Graham et al., 2006; Mathwin et al., 2022). Evaluation of the program could establish whether proficiency in alphabet and orthographic knowledge (of alphabet-letters) results in effortless recognition, retrieval, and accurate writing of alphabet-letters as seen in orthographic knowledge for words (Apel et al., 2018).

Finally, research has asserted that handwriting instruction in the classroom is not occurring at recommended levels (de Abreu Malpique et al., 2022; Graham, 2019). The results from this study support calls from other researchers (Håland et al., 2019; Vander Hart et al., 2010; Wyatt-Smith et al., 2018) to advocate strategies to help facilitate opportunities for recommended handwriting instruction to be provided by teachers and specialists, such as occupational therapists, in the early years at school.

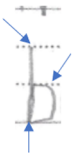
Limitations

There were several limitations to this study. This study's interpretation of measuring alphabet and orthographic knowledge for correct alphabet-letter-writing is exploratory. To confirm the assumptions made, further investigation and validation is necessary. Similarly, knowledge of orthographic skills in children's alphabet-letter-writing skills is in the emergent stage and the exact definition of orthography in relation to alphabet-letters verses words for spelling and reading is scarce. The outcome measure used procedural analysis of different writing tasks, scoring system, dotted-third lined paper, and evaluated different legibility components to other handwriting assessments. Further research would enhance its validity and usefulness in classroom and therapy contexts. Additionally, this study was restricted to investigating the impact of children's alphabet and orthographic knowledge on alphabet-letter-writing skills and did not examine other contributing elements of children's handwriting performance such as individual factors (literacy, cognitive, and motor skills) and external factors (socioeconomic background, parent's education). Ethical restrictions prevented information being gathered about classroom handwriting practices to determine which aspects of alphabet-letter-writing measured by this assessment tool, children had received instruction. Therefore, the results of this study need to be interpreted with caution. Finally, this study was carried out in Western Australian schools. Replication of the research in other Australian states and countries which use the Latin alphabet is needed to discover similarities and differences in the abilities and development of early writers.

Conclusion

The results of this study found that on average, across the three writing conditions, Y1 children could accurately write between eight and nine, and Y2 children 12–13 of the 26-lowercase alphabet-letters. All alphabet and orthographic subskills (of alphabet-letters) attracted some difficulty for both Y1 and Y2 children suggesting many children on the study had inaccurate and/or inadequate alphabet and orthographic knowledge, impacting their ability to correctly write alphabet-letters. Y2 children were significantly better than Y1 children at correct alphabet-letter-writing and with recalling the alphabet sequence, sound-to-letter translation, letter-shape recall, and letter-orientation. Otherwise, there was either no or minimal difference in how Y1 and Y2 children formed (besides orientation) and placed alphabet-letters. The results suggested that once children learn letter-formation, letter-legibility and letter-placement of alphabet-letters in Y1, whether there are errors involved or not, children continue to write this way, in most writing conditions, into Y2.

Appendix A

Letter	Legibility Guidelines	Letter Placement Guidelines
a	1. Slant of the vertical line must be between 75 and 105 degrees. e.g. Not – or 2. Must have a closed join and no extended lines (up to 1mm gap or extension allowed), between the starting point of the curved shape and the top of the vertical line, e.g. Not – or or 3. There must be a 2 mm joined connection between the ascending line (after the curved shape) and the vertical downward line. e.g. Not – 4. The ascending line (after the curved shape) and the vertical downward line must be joined, with no visible opening. e.g. Not – 1. There must be an opening between the curved line and the vertical ascending line of 2mm – 8 mm. e.g. Not – or	
b	1. Slant of the vertical line must be between 75 and 105 degrees e.g. Not – or 2. Must have a closed join, with no extended lines (up to 1mm gap or extension allowed), between the curved shape and the base of the vertical line. e.g. Not – or 3. There must be a 2 mm joined connection between the descending and ascending vertical line (before the curved shape). e.g. Not – 4. There must be no visible opening between the descending and ascending vertical line (before the curved shape). e.g. Not – 2. There must be an opening between the descending vertical line and the curved line of 2mm – 8 mm. e.g. Not – or	

Legibility-Rules and Letter-Placement Guidelines

Funding Open Access funding enabled and organized by CAUL and its Member Institutions.

Declarations

Conflict of interest The authors have no known conflicts of interest to disclose and received no funding from external groups.

Ethics approval and consent to participate Full research ethics was received from The University of Sydney [Project No: 2019/261], the Government of Western Australian Department of Education [D21/0029448] and the Catholic Education Western Australian [RP2020/24].

References

Abbott, R. D., & Berninger, V. W. (1993). Structural equation modelling of relationships among developmental skills and writing skills in primary-grade and intermediate-grade writers. *Journal of Educational Psychology*, *85*(3), 478–508. https://doi.org/10.1037/0022-0663.85.3.478.

Apel, K., Brimo, D., Wilson-Fowler, E., Vorstius, C., & Radach, R. (2013). Children develop initial orthographic knowledge during storybook reading. *Scientific Studies of Reading*, *17*(4), 286–302. https://doi.org/10.1080/10888438.2012.692742.

Apel, K., Henbest, V., & Masterson, J. (2018). Orthographic knowledge: Clarifications, challenges, and future directions. *Reading and Writing: An Interdisciplinary Journal*, *32*(4), 873–889. https://doi.org/10.1007/s11145-018-9895-9.

Barnett, A. L., Prunty, M., & Rosenblum, S. (2018). Development of the handwriting legibility scale (HLS): A preliminary examination of reliability and validity. *Research in Developmental Disabilities*, *72*, 240–247. https://doi.org/10.1016/j.ridd.2017.11.013.

Challita, J., Chapparo, C., Hinitt, J., & Heard, R. (2019). Effective occupational therapy intervention with children demonstrating reduced social competence during playground interactions. *British Journal of Occupational Therapy*, *82*(7), 433–442. https://doi.org/10.1177/0308022619832467.

Chapparo, C., & Ranka, J. (2014). *The perceive, recall, plan & perform system assessment course manual: PRPP assessment course*. Department of Occupational Therapy, University of Sydney.

Chrisman, S. L., Burtner, P. A., Candler, C., & Neville, M. (2013). Identifying children with and without handwriting difficulties using the print tool. *Journal of Occupational Therapy Schools & Early Intervention*, *6*(3), 241–254. https://doi.org/10.1080/19411243.2013.850960.

Christensen, C. A. (2005). The role of orthographic-motor integration in the production of creative and well-structured written text for students in secondary school. *Educational Psychology*, *25*(5), 441–453. https://doi.org/10.1080/01443410500042076.

Collette, D., Anson, K., Halabi, N., Schlierman, A., & Suriner, A. (2017). Handwriting and common core state standards: Teacher, occupational therapist, and administrator perceptions from New York state public schools. *The American Journal of Occupational Therapy*, *71*(6), 7106220010p1–7106220010p9. https://doi.org/10.5014/ajot.2017.021808.

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. An Interdisciplinary Journal*, *36*(1), 1–27. https://doi.org/10.1007/s11145-022-10294-2.

Diekema, S., Deitz, J., & Amundson, S. (1998). Test-retest reliability of the evaluation tool of children's handwriting-manuscript. *The American Journal of Occupational Therapy*, *52*(4), 248–255. https://doi.org/10.5014/ajot.52.4.248.

Doug, R. (2019). Handwriting: Developing pupils' identity and cognitive skills. *International Journal of Education and Literacy Studies*, *7*(2), 177–188. https://doi.org/10.7575/aiac.ijels.v.7n.2p.177.

Duiser, I. H. F., Ledebt, A., van der Kamp, J., & Savelsbergh, G. (2020). Persistent handwriting problems are hard to predict: A longitudinal study of the development of handwriting in primary school. *Research in Developmental Disabilities*, *97*, 103551–103551. https://doi.org/10.1016/j.ridd.2019.103551.

Duiser, I., Ledebt, A., van der Kamp, J., & Savelsbergh, G. (2022). Does learning to write and type make a difference in letter recognition and discrimination in primary school children? *Journal of Cognitive Psychology*, *34*(6), 691–702. https://doi.org/10.1080/20445911.2022.2060240.

Fogel, Y., Rosenblum, S., & Barnett, A. (2022). Handwriting legibility across different writing tasks in school-aged children. *Hong Kong Journal of Occupational Therapy*, *35*(1), 44–51. https://doi.org/10.1177/15691861221075709.

Gosse, C., Parmentier, M., & Van Reybroeck, M. (2021). How do spelling, handwriting speed, and handwriting quality develop during primary school? Cross-classified growth curve analysis of children's writing development. *Frontiers in Psychology*, *12*, 685681–685681. https://doi.org/10.3389/fpsyg.2021.685681.

Graham, S. (2019). Changing how writing is taught. *Review of Research in Education*, *43*(1), 277–303. https://doi.org/10.3102/0091732X18821125.

Graham, S., Weintraub, N., & Berninger, V. (2001). Which manuscript letters do primary grade children write legibly? *Journal of Educational Psychology*, *93*(3), 488–497. https://doi.org/10.1037/0022-0663.93.3.488.

Graham, S., Struck, M., Santoro, J., & Berninger, V. (2006). Dimensions of good and poor handwriting legibility in first and second graders: Motor programs, visual-spatial arrangement, and letter formation parameter setting. *Developmental Neuropsychology*, *29*(1), 43–60. https://doi.org/10.1207/s15326942dn2901_4.

Graham, S., Harris, K., Mason, L., Fink-Chorzempa, B., Moran, S., & Saddler, B. (2008). How do primary grade teachers teach handwriting? A national survey. *Reading and Writing: An Interdisciplinary Journal*, *21*(1–2), 49–69. https://doi.org/10.1007/s11145-007-9064-z.

Greifeneder, R., Zelt, S., Seele, T., Bottenberg, K., & Alt, A. (2012). Towards a better understanding of the legibility bias in performance assessments: The case of gender-based inferences. *British Journal of Educational Psychology*, *82*(3), 361–374. https://doi.org/10.1111/j.2044-8279.2011.02029.x.

Håland, A., Hoem, T., & McTigue, E. (2019). Writing in first grade: The quantity and quality of practices in norwegian classrooms. *Early Childhood Education Journal*, *47*(1), 63–74. https://doi.org/10.1007/s10643-018-0908-8.

Heid, M. (2022). Here's how teachers can foil ChatGPT: Handwritten essays. *Washington Post* https://www.washingtonpost.com/opinions/2022/12/29/handwritten-essays-defeat-chatgpt/.

Hiatt, B. (2021. April 6). WA teachers urged to improve students' handwriting skills to make Year 12 exam answers legible. *West Australian* https://thewest.com.au/news/education/wa-teachers-urged-to-improve-students-handwriting-skills-to-make-year-12-exam-answers-legible-ng-b881837158z.

Jiménez, J. E. (2017). Early grade writing assessment: An instrument model. *Journal of Learning Disabilities*, *50*(5), 491–503. https://doi.org/10.1177/0022219416633127.

Karlsdottir, R., & Stefansson, T. (2002). Problems in developing functional handwriting. *Perceptual and Motor Skills*, *94*(2), 623–662. https://doi.org/10.2466/pms.2002.94.2.623.

Khoury-Metanis, A., & Khateb, A. (2022). Exploring the writing-reading connection among arabic-speaking kindergarten children: The role of fine motor skills and orthographic knowledge. *Reading and Writing: An Interdisciplinary Journal*, *35*(7), 1525–1547. https://doi.org/10.1007/s11145-021-10235-5.

Kim, Y. S., Otaiba, S. A., Puranik, C., Folsom, J., & Gruelich, L. (2014). The contributions of vocabulary and letter-writing automaticity to word reading and spelling for kindergartners. *Reading and Writing: An Interdisciplinary Journal*, *27*(2), 237–253. https://doi.org/10.1007/s11145-013-9440-9.

Kim, Y. S., Gatlin, B., Otaiba, A., S., & Wanzek, J. (2018). Theorization and an empirical investigation of the component-based and developmental text writing fluency construct. *Journal of Learning Disabilities*, *51*(4), 320–335. https://doi.org/10.1177/0022219417712016.

Longcamp, M., Zerbato-Poudou, M., & Velay, J. (2005). The influence of writing practice on letter recognition in preschool children: A comparison between handwriting and typing. *Acta Psychologica*, *119*(1), 67–79. https://doi.org/10.1016/j.actpsy.2004.10.019.

Lowe, S., & Chapparo, C. (2010). Work at school: Teacher and parent perceptions about children's participation. *Work-a Journal of Prevention Assessment & Rehabilitation*, *36*(2), 249–256. https://doi.org/10.3233/WOR-2010-1025.

Mackenzie, N. (2021). *Handwriting resource links: State by state* Primary English Teaching Association Australia. https://petaa.edu.au/litportal/litportal/Resources-for-Curriculum/Upper-primary/Writing/Handwriting-and-Keyboarding/handwriting_state.aspx.

Mackenzie, N. M., & Spokes, R. (2018). Handwriting, keyboarding or both? In N. M. Mackenzie, & J. Scull (Eds.), *Understanding and supporting Young Writers from Birth to 8* (pp. 137–164). Routledge.

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

Mariano, E., Campbell-Evans, G., & Hunter, J. (2022). Writing assessment in early primary classrooms: Thoughts from four teachers. *The Australian Journal of Language and Literacy*, *45*(1), 85–101. https://doi.org/10.1007/s44020-022-00007-1.

Mathwin, K., Chapparo, C., & Hinnit, J. (2022). Children with handwriting difficulties: Developing orthographic knowledge of alphabet-letters to improve capacity to write alphabet symbols. *Reading and Writing: An Interdisciplinary Journal*, *35*(4), 919–942. https://doi.org/10.1007/s11145-021-10207-9.

McCutchen, D. (2000). Knowledge, processing, and working memory: Implications for a theory of writing. *Educational Psychologist*, *35*(1), 13–23. https://doi.org/10.1207/S15326985EP3501_3.

McLean, E., & Griffiths, K. (2022). *Writing and writing instruction. An overview of the literature* https://www.edresearch.edu.au/sites/default/files/2022-02/writing-instruction-literature-review.pdf.

Medwell, J., & Wray, D. (2019). *What's the use of handwriting?* http://s7d9.scene7.com/is/content/NewellRubbermaid/Write%20Your%20Future/White%20Paper%20FINAL%203APR2017%20w%20logo.pdf.

Mills, C., Chapparo, C., & Hinitt, J. (2016). The impact of an in-class sensory activity schedule on task performance of children with autism and intellectual disability: A pilot study. *The British Journal of Occupational Therapy*, *79*(9), 530–539. https://doi.org/10.1177/0308022616639989.

Molfese, V., Beswick, J., Molnar, A., & Jacobi-Vessels, J. (2006). Alphabetic skills in preschool: A preliminary study of letter naming and letter writing. *Developmental Neuropsychology*, *29*(1), 5–19. https://doi.org/10.1207/s15326942dn2901_2.

New South Wales Department of Education and Training (1987). *Handwriting: Teaching the foundational approach* https://www.australianschoolfonts.com.au/assets/resources/k6_handwriting.pdf.

Nott, M., & Chapparo, C. (2012). Exploring the validity of the perceive, recall, plan and perform system of task analysis: Cognitive strategy use in adults with brain injury. *The British Journal of Occupational Therapy*, *75*(6), 256–263. https://doi.org/10.4276/030802212X13383757345067.

Ouellette, G. P., & Sénéchal, M. (2008). A window into early literacy: Exploring the cognitive and linguistic underpinnings of invented spelling. *Scientific Studies of Reading*, *12*(2), 195–219. https://doi.org/10.1080/10888430801917324.

Overvelde, A., & Hulstijn, W. (2011). Handwriting development in grade 2 and grade 3 primary school children with normal, at risk, or dysgraphic characteristics. *Research in Developmental Disabilities*, *32*(2), 540–548. https://doi.org/10.1016/j.ridd.2010.12.027.

Perea, M. (2015). Neighbourhood effects in visual word recognition and reading. In A. Pollatsek, & R. Treiman (Eds.), *The Oxford Handbook of Reading* (pp. 76–87). Oxford University Press.

Puranik, C., & Apel, K. (2010). Effect of assessment task and letter writing ability on preschool children's spelling performance. *Assessment for Effective Intervention*, *36*(1), 46–56. https://doi.org/10.1177/1534508410380040.

Puranik, C. S., & Lonigan, C. (2011). From scribbles to scrabble: Preschool children's developing knowledge of written language. *Reading and Writing: An Interdisciplinary Journal*, *24*(5), 567–589. https://doi.org/10.1007/s11145-009-9220-8.

Puranik, C. S., & Lonigan, C. J. (2014). Emergent writing in preschoolers: Preliminary evidence for a theoretical framework. *Reading Research Quarterly*, *49*(4), 453–467. https://doi.org/10.1002/rrq.79

Puranik, C. S., Lonigan, C. J., & Kim, Y.-S. (2011). Contributions of emergent literacy skills to name writing, letter writing, and spelling in preschool children. *Early Childhood Research Quarterly*, *26*(4), 465–474. https://doi.org/10.1016/j.ecresq.2011.03.002

Puranik, C. S., Petscher, Y., & Lonigan, C. J. (2014). Learning to write letters: Examination of student and letter factors. *Journal of Experimental Child Psychology*, *128*, 152–170. https://doi.org/10.1016/j.jecp.2014.07.009.

Ritchey, K. D. (2008). The building blocks of writing: Learning to write letters and spell words. *Reading and Writing: An Interdisciplinary Journal*, *21*, 27–47. https://doi.org/10.1007/s11145-007-9063-0.

Rodríguez, C., & Villarroel, R. (2017). Predicting handwriting difficulties through spelling processes. *Journal of Learning Disabilities*, *50*(5), 504–510. https://doi.org/10.1177/0022219416633863.

Roston, K., Hinojosa, J., & Kaplan, H. (2008). Using the Minnesota handwriting assessment and handwriting checklist in screening first and second graders' handwriting legibility. *Journal of Occupational Therapy Schools & Early Intervention*, *1*(2), 100–115. https://doi.org/10.1080/19411240802312947.

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 (2021). *Western Australian handwriting continuum* https://k10outline.scsa.wa.edu.au/home/teaching/p-10-handwriting-continuum.

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

Spilling, E. F., Rønneberg, V., Rogne, W., Roeser, J., & Torrance, M. (2023). Writing by hand or digitally in first grade: Effects on rate of learning to compose text. *Computers and Education*, 198. https://doi.org/10.1016/j.compedu.2023.104755.

Stefansson, T., & Karlsdottir, R. (2003). Formative evaluation of handwriting quality. *Perceptual and Motor Skills*, *97*(3_suppl), 1231–1264. https://doi.org/10.2466/pms.2003.97.3f.1231.

The University of Sydney (2023). *Exams*. https://www.sydney.edu.au/students/exams/in-person.html.

Treiman, R., & Kessler, B. (2014). *How children learn to write words*. Oxford University Press. https://doi.org/10.1093/acprof:oso/9780199907977.001.0001.

University of Oxford (2023). *In-Person Exams* https://www.ox.ac.uk/students/academic/exams/completing-an-exam/in-person-exams.

Vander Hart, N., Fitzpatrick, P., & Cortesa, C. (2010). In-depth analysis of handwriting curriculum and instruction in four kindergarten classrooms. *Reading and Writing: An Interdisciplinary Journal*, *23*(6), 673–699. https://doi.org/10.1007/s11145-009-9178-6.

Weintraub, N., & Graham, S. (2000). The contribution of gender, orthographic, finger function, and visual-motor processes to the prediction of handwriting status. *OTJR (Thorofare N J)*, *20*(2), 121–140. https://doi.org/10.1177/153944920002000203.

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 and Education*, *95*, 19–35. https://doi.org/10.1016/j.compedu.2015.12.001.

Wyatt-Smith, C., Jackson, C., Borooah, V., & Whalley, K. (2018). *Summary of the research report of the Australian writing survey* 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=