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The effect of pen and paper or tablet computer on early writing – A pilot study

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ABSTRACT

One consequence of the ongoing controversy on the implementation of digital tools in early writing instruction is a need to investigate the effect of different writing instruction tools such as pen(cil) and paper and tablet computers on early writing. The purpose of this pilot study is to develop a study design and a writing test to investigate the effect of writing instruction tool (tablet computer vs. pen and paper) and test format (digital vs. pen-and-paper) on early writing outcomes. For the writing test, our pilot study shows that pupils assessed by the digital test format wrote faster compared with those assessed by pen-and-paper format, independent of the writing instruction tool. Given the limitations of this pilot study in scope and its quasi-experimental nature, we provide some suggestions for the design of a larger scale study by taking into account the rapid development of the field of early writing instruction.

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1. Introduction

In many European countries, in particular the Nordic countries, Information Communication Technologies (ICT) including computers, tablet computers and smartphones are part of the school infrastructure.¹ Use of ICT has become a natural part of teaching and learning at school (Berge, 2014; Liabo, Simon, Tripney, Daniel-Gittens, & Elwick, 2014; Lim & Oakley, 2013) and *digital literacy* is a core element in the national curriculum. In Norway, for example, the latest reform of compulsory education in 2006 – the ‘Knowledge Promotion Reform’ (*Kunnskapsløftet*) – added digital literacy as one of five core skills, among them reading and writing skills.² At the same time, an increasing use of ICT also within reading and writing instruction at elementary level challenges proponents of such traditional learning devices as printed books, paper and pencil (Selwyn, 2012), among them many teachers and parents.

While *digital writing instruction* (synonyms: keyboarding, typing) is gaining in importance at school in many countries, *handwriting instruction, in particular cursive writing instruction*, appears to lose ground, at least in some countries: following the *Common Core Curriculum Standards* 45 states in the United States have removed *cursive writing* and replaced it with keyboard writing (in addition to print writing instruction by using pen and paper), while seven states still favor *cursive writing* instruction.³ In Finland, from autumn 2016 first-graders will learn both: printing and forming words with upper and lower

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¹ In the Nordic countries, schools are highly equipped with ICT compared with other European countries (European Schoolnet, 2013).

² Norwegian Directorate for Education and Training (2012). Framework for Basis Skills.

³ <http://www.nydailynews.com/life-style/states-fight-cursive-classroom-article-1.1518352> [retrieved, September 9th, 2015].

case letters, and keyboard skills (Søby, 2015). While some countries seem to put a stronger focus on printing letters and keyboard writing, in other countries, however, we can observe another trend. There are indications that in France the current curriculum puts a stronger focus than its predecessor on *cursive* handwriting.⁴ To make their argument, educators refer to current research in the field of neuroscience and education that stress the importance of the 'haptics of handwriting' (Mangen & Velay, 2010) for brain development in general, and later academic achievement (e.g. James & Engelhardt, 2012; Longcamp et al., 2008; Longcamp, Zerbato-Poudou, & Velay, 2005), such as reading achievement (Dinehart & Manfra, 2013). To provide another example from the US, North Carolina has returned to cursive writing, defining this as a new mandatory subject, as opposed to those states following the Common Core Standards.⁵

Adhering to the *writing-to-read paradigm*, proponents of writing instruction methods based on digital writing tools (e.g. Graham & Hebert, 2011; Graham & Hebert, 2010; Trageton, 2009) argue that writing is easier for children than reading and should therefore be taught first, and that typing is easier and faster to learn than handwriting (Genlott & Grönlund, 2013; Hultin & Westman, 2013). In particular, for children who are struggling with fine motor skills, this method might reduce frustration in their earlier period of writing instruction (Goldberg, Russell, & Cook, 2003).

In contrast, proponents of traditional, pen-and-paper-based writing instruction methods refer to studies in the field of neuroscience, where studies show a positive association between *handwriting* and activities in certain areas of the brain (brain circuits). Further, there is evidence of a positive relationship between good handwriting skills and further academic outcomes, such as reading (Dinehart & Manfra, 2013), reasoning and memorizing skills (Longcamp et al. 2008; Longcamp et al., 2005; Mangen & Velay, 2010; Olivier & Velay, 2009), also for older student populations. By comparing two groups of university students, one group using pen and paper and another group using a laptop for note-taking, Mueller and Oppenheimer (2014) found that even though laptop use was related to easier and more extensive note-taking, these notes were rather 'non-generative', with little learning outcome. Generative note taking of the group using a pen and paper, on the other hand, was more strongly associated with improved learning (for example summarizing, paraphrasing).

Previous studies in the field of writing primarily focus on older student populations such as university students (Fortunati & Vincent, 2014; Taipale, 2014, 2015), secondary school students (Cheung, 2012; Liabo et al., 2014; Littlejohn, Beetham, & McGill, 2012), or students with learning disabilities (Berninger, Abbott, Augsburger, & Garcia, 2009; Berninger, Nagy, Tanimoto, Thompson, & Abbott, 2015). Studies addressing younger populations, however, are relatively few (e.g. Genlott & Grönlund, 2013; Longcamp et al. 2008). Limiting the scope to early writing instruction among third-graders, the purpose of this pilot study is to develop a study design and a writing test to investigate the effect of writing instruction tool (tablet computer vs. pen and paper) and test format (digital vs. pen-and-paper) on early writing outcomes. Thus, this study might serve as a point of departure for the research community to develop a larger scale study, to add further to the ongoing debate on writing instruction.

In the following background section, we develop our main research questions leading our pilot study by outlining differences related to handwriting and typing, and briefly review existing research on the importance of handwriting skills for academic achievement on the one hand, and research on the potential of digital writing tools for early writing on the other. Second, in the method section we describe the design of our pilot study including the sample, data collection, the writing test developed, and the operationalization of the main outcomes. In the third section, we present the main results of our study. In the concluding section, we discuss the value of our small-scale pilot study, being aware of its main limitations, and give some implications for a future study on a larger scale and taking into account the rapid changes in the field.

2. Background

2.1. Differences between handwriting and typing

Even though the two *modes* of writing, handwriting and typing, serve the same purpose, to communicate, they differ in three aspects related to the tool used (see Mangen & Velay, 2010). First, handwriting is an activity conducted by using *one* hand, while professional typing requires two hands.⁶ Second, if using pen and paper, writers are urged to pay higher visual attention to the writing process by leading their attention to the tip of the pen. In contrast, the visual attention of keyboard users, is supposed to be more separated from the 'haptics of writing' process. Thus, for typing, the writing process happens in two distinct spaces, motor (*keyboard*) and visual space (*the screen*). Third, for letter writing, the writer by hand has to form every single letter ('selfmades') on her or his own, while the typist just has to identify letters and press them on the keyboard while writing, because these letters are 'readymades' (Mangen & Velay, 2010).

⁴ <http://www.theguardian.com/science/2014/dec/16/cognitive-benefits-handwriting-decline-typing> [retrieved, September 9th2015].

⁵ Urist, J. (2013, Sept. 3). Learning cursive writing: Is it worthwhile or a waste of time? TODAY Parents. Retrieved from <http://www.today.com/parents/learning-cursive-writing-it-worthwhile-or-wasted-time-8C11045379>.

⁶ One can think of exceptions like 'digital natives' writing sms by using one hand.

2.2. Research overview

To our knowledge, there are relatively few studies with an experimental or quasi-experimental design, which explicitly compare the impact of writing instruction methods by applying either a digital writing tool (keyboard or tablet) or pencil and paper on early writers writing.⁷ In sum, we can relate the existing studies to three different theoretical traditions within socio-cultural learning theory, cognitive writing theory, and neuroscience and learning theory (see Wollscheid, Sjaastad, & Tømte, 2016).

Studies in the tradition of *socio-cultural learning theory* (Vygotsky, 1978) put the emphasis on writing as a human activity in a social context, i.e. in interaction with the environment, including instructors and peer-learners. Here, the writing outcome, the text, is understood as an ‘artifact of an activity’ that is socially mediated (Säljö & Moen, 2001). In sum, studies in that tradition, e.g. two from Sweden (Genlott & Grönlund, 2013; Hultin & Westman, 2013) draw on a *learning to read by writing approach* by introducing the computer/keyboard as an alternative writing tool to pen and paper. Overall, they indicate that children who used the computer at an early stage produce longer text, without mastering all the letters at that stage. At the same time, the key point raised by one of the studies (Van Leeuwen & Gabriel, 2007) is that the way of implementing the tool in interaction with the learners, and the writing curriculum, are critical to a greater degree than the writing tool itself for writing instruction.

Studies drawing upon a *cognitive writing theoretical perspective* have a longer tradition in early writing instruction (Berninger & Hart, 1992; Berninger et al., 1992). According to Flower and Hayes (1981) for example the writing process consists of three component *low-level transcription skills* i.e. handwriting, keyboarding and spelling; *executive functions*, including conscious attention, planning, reviewing, revising, and self-regulation strategies; and *high-level text generation skills*. This model presents the multidimensional process of learning to write by a triangle of the three components above, with the working memory at its center, and as a limited resource. As a foundation for the development of further writing skills, *transcription skills* (low-level writing skills) are the first to develop, enabling writers to convert ideas and spoken language into written text. For early writers such as pupils in elementary school the development of transcription skills means to develop a fluent and legible form of handwriting or fluent typing, and spelling skills (Berninger et al., 2002). Overall, previous studies within this tradition rather point to an advantage on the impact of handwriting compared with typing on such early writing outcomes as writing speed and spelling (Berninger et al., 2009; Connelly, Gee, & Walsh, 2007; Crook & Bennett, 2007; Read, 2007).

Based on these studies, however, we cannot conclude that better writing outcomes are the consequence of traditional pen and paper instruction method. Based on the design applied in these studies, however, we can conclude that better writing outcomes in favor of traditional instruction methods are the consequence of a longer experience in handwriting compared with typing.

During recent years, a couple of *studies within neuroscience and learning* have been published. Briefly, these studies have primarily investigated how different writing modes, such as handwriting, typing, or tracing, influence brain activation. There are indications that early printing of letters by hand, in the sense of a ‘bodily dimension’ of writing (Taipale, 2015), compared with typing or tracing letters, activates specific brain circuits during letter perception in a particular way. Due to the individual’s motor experience, these studies show that single letters, if *printed*, process differently from words, partly due to the individual’s motor experience. Overall, these studies appear to favor handwriting instruction compared with typing instruction methods. As a reminder there is evidence that handwriting experience, i.e. ‘the motor-graphic experience’ or the ‘haptics of writing’ (Mangen & Velay, 2010) facilitates letter perception via brain processes and reading skills (James & Engelhardt, 2012; Longcamp et al., 2005, 2008; Mangen & Velay, 2010). This evidence is in line with findings of earlier studies that have shown positive associations between good handwriting skills and different dimensions of academic skills (Dinehart, 2015; Dinehart & Manfra, 2013). However, applying a more advanced study design controlling for earlier writing experience, Ouellette and Tims (2014) have shown no significant differences in learning between second-graders who had practiced spelling of so-called new *non-words* by printing and those who had practiced them by typing.

The aim of this study is twofold. First, this study aims to pilot a study design, which accounts for the effect of writing instruction tool and test-format on early writing outcomes. Second, it aims to develop a writing test for re-use and further development in a larger scale study, in light of the dynamic development of the field. In our pilot study, we concentrate on writing speed and spelling outcomes, but we are aware of limitations in terms of the complexity of the writing construct that further captures qualitative dimensions (e.g., style) and subjective dimensions such as pupils’ motivation to write.

We developed a study design and a writing test to address the following research question: what is the effect of the two different writing instruction tools in early writing instruction—pen and pencil and tablet computer—on early writing outcomes, writing speed, and spelling? To address this question, we compare pupils in a school with a traditional writing instruction method based on pen and paper (reading by writing) and pupils in another school using tablet computers in early writing instruction (writing to read). Further, we assume that test format (pen and paper and digital format) has an effect on the writing test results. Thus, the second research question is: what are the differences in writing test results according to test

⁷ According to Juzwik et al. (2006) less than five percent of studies in the field of writing address elementary school pupils and even fewer studies applied an experimental or quasi-experimental study design.

format, comparing pupils who received writing instruction by tablet computers and pupils who received handwriting instruction?

3. Method

3.1. Data collection

The study was conducted in November 2014. Choosing a strategic sampling strategy, we selected two primary/elementary schools located in a suburban area of Oslo with two different pedagogical profiles with respect to the writing instruction tool used in early writing instruction. Each school served approximately 400 pupils enrolled in class 1–7, and had approximately 60 employees, among them 40 teachers. The share of pupils with minority language background was slightly greater than the average for Norway.

We visited the two case schools twice. On the first visit, we interviewed pupils, teachers and the school principal; on the second visit, we carried out the writing test. At School 1, we interviewed 10 pupils and three teachers (one classroom teacher, two teachers with administrative responsibilities); at School 2 we interviewed 19 pupils, two teachers and the school leader. At both schools, we interviewed pupils in groups, and teachers and the school principal in separate, individual interviews. Topics raised included the organization of the school, the pedagogical profile and the technological infrastructure. Further, we conducted writing tests, in one class of School 1 (with 15 pupils), and in two classes of School 2 (covering in total 32 pupils). Moreover, parents of the group of pupils involved in the study were asked to accept or refuse their child's participation. The procedure followed the ethical guidelines of the Data Protection Official organized by the Norwegian Social Science Data Services (NSD).

In the following, we describe the two schools according to their individual pedagogical profile with its focus either on traditional handwriting or on writing instruction using a tablet computer.

3.2. School 1: traditional writing instruction with focus on reading instruction

Instead of categorizing School 1 by a clearly defined writing instruction method, we can describe this school by a clearly defined strategy for *reading instruction*, and by the use of pen and paper in writing instruction. According to our informants, teachers were obliged to use a particular learning tool for reading instruction, and the school library was the 'heart of the school'. A full-time employed reading teacher worked with pupils with weak reading outcomes, and the school library had a wide offer of programs addressing reading. In brief, the school library was supposed to make up an important part of the school's identity. The writing instruction method at School 1 was described as rather 'traditional'; the test-taking teacher referred to the method by using block letter writing instruction followed by cursive writing instruction in grade 3. In general, our informants reported that teachers were relatively free to choose and organize writing instruction within a certain framework. Teachers reported a certain degree of freedom in using digital tools in their lessons.

3.3. School 2: writing instruction by tablet computer

The use of tablet computers made up a core element in teaching and learning. School 2 had a clearly formulated strategy of using tablet computers across all subjects, not only in writing instruction. The school principal referred to the 'Writing to read method' (Trageton, 2003) as an argument for using tablet computers in early writing instruction. Teachers seem to have less freedom to choose instructional methods that do not employ tablet computers. Teachers had received some training in how to implement tablet computers in their classes, and every child has her or his own tablet computer. Our informants referred to specific applications (apps) used for letter instruction and spelling instruction. With the introduction of tablet computers for early writing instruction, alternative strategies in writing instruction had become less important at School 2, according to our informants.

In sum, while School 1 applies a strategy that can be described as 'writing by the means of reading', School 2 applies a strategy that can be described as 'writing by the means of tablet computer (pad)'.

*Design: writing instruction * test format (2 × 2)(–1) group design*

The overall aim of our study was to investigate the effect of writing instruction tools on early writing outcomes including writing speed and spelling. To control for test format (paper and pencil, digital test format) we applied a 2 × 2(–1) group design. Against the backdrop that pupils in School 1 exclusively received writing instruction using pencil and paper at school,

Table 1

The writing instruction tool and testing format provided for the three groups of pupils.

	Group 1 (school 1), n = 15	Group 2 (school 2), n = 14	Group 3 (school 2), n = 18
Writing instruction tool applied	Writing by reading (pen and paper)	Reading by writing (tablet computer)	Reading by writing (writing by tablet)
Testing format	Pencil and paper	Pencil and paper	Digital test (tablet)

and without knowing whether those pupils had any experience in using tablet computers in non-school contexts, we only applied a paper-and-pencil test format at School 1, providing three different combinations (Table 1). This means, we administered the pilot study to only three instead of four potential test groups. However, most writing instruction methods might include some kind of digital writing, which will open up for the full 2×2 -design in a future study.

3.4. Writing test

To study writing speed among the students from the two schools one required a format for testing that could apply for all the groups in the study. There are several standardized tests for students' writing skills, normally focused on rate/speed and quality (O'Mahony, Dempsey, & Killeen, 2008). Due to the number of factors that can influence the development of handwriting, including factors such as the age at which children start their formal learning in handwriting, different approaches to teaching, such as timing and type of introduction of cursive writing, it is necessary to pay attention to local norms when assessing students' writing skills (O'Mahony et al., 2008). Our test included exercises typical for the age of this student group (third-graders) in Norwegian elementary schools. To develop a test that accounted for age level and national context, we selected text material from Norwegian children's literature, which was comparable with third grade curriculum textbooks.

Moreover, speed of handwriting has usually been assessed by recording time taken to write a specific text, or by the amount of text produced within a specific time period (Ferrier, Horne, & Singleton, 2013). Studies of methods to assess writing speed point to the limitation of such methods due to the complexity of the different processes of writing (Rosenblum, Weiss, & Parush, 2003). However, three main methods have been adopted: 1) *writing to dictation*; 2) *copying/translating*; and 3) *free writing* (Ferrier et al., 2013). According to several studies, copying or translating tasks are useful for testing younger students and have been shown to be effective for observing the development for writing speed (Ferrier et al., 2013). However, in written examinations, various cognitive and motivational factors affect writing speed, and physiological factors such as muscle fatigue are more likely to become salient only over a prolonged period of writing. Thus, longer tests or writing to dictation can overcome this problem to some extent (O'Mahony et al., 2008). For tasks of free writing a much more extensive range of cognitive skills is required and this task is more demanding than to copy a text or to write to dictation. Among these skills are, for example, the generation of ideas and their translation into written form (Ferrier et al., 2013). This in turn involves not only linguistic processes, but also the application of logical thinking, structuring and self-monitoring (Berninger, Nielsen, Abbott, Wijsman, & Raskind, 2008). For K-12 level, few studies have investigated the effect of delivery mode (e.g. computerized or written modes) on writing test performance. At the same time, these studies often are limited to small, non-representative samples. Even so, results suggest that mode does have an effect on test score, for example, when it comes to students' computer familiarity (Horkay, Bennett, Allen, Kaplan, & Yan, 2006). Several studies have looked at the relationship of computer familiarity to writing test performance. Although not entirely consistent, the results suggest that computer and paper writing tests may not measure the same skill for all students. Wolfe, Bolton, Feltovich, and Niday (1996), for example, found that secondary school students with less experience writing on keyboard were disadvantaged by having to test that way.

To capture different dimensions of early writing, according to the literature review above, we developed a writing test that consists of the following three tasks with which the pupils were familiar: transcription of a given text, dictation, and free writing.

To solve the *transcription task* pupils were presented with a page of written history inspired by a Norwegian children's fairytale (the Bear and the Fox), to transcribe as much text as they could within 7 min. Measure: writing speed.

The *dictation task* consisted of ten sentences read aloud by the teacher. The teacher read each sentence twice, pausing for 20 s before reading the next sentence. Pupils were asked to write down the sentences subsequently. They were given 30 s per sentence. They were allowed to start writing while the teacher was reading. Measures: writing speed, spelling, and memory.

To solve the *free writing task* pupils were asked to choose their favorite season and write a story taking place in this season within a timeframe of 7 min. If they finished their history before time, they were asked to write a new history. Measure: writing speed, spelling, and qualitative dimensions of writing. [See Appendix 1 for a translated version of the writing test].

3.5. Measures

Writing speed: We operationalized writing speed as the number of words written as a result of each of the three tasks (transcription, dictation and free writing).

Share of mistakes (absolute number of mistakes/number of words written): We distinguished between the share of spelling mistakes and other writing mistakes, including punctuation, use of capitalization, and lack of space between words.

4. Results

In the following section, we present the main results of our pilot study, first with regard to the effect of writing instruction tool on early writing outcomes as assessed by the paper-and-pencil test; second, with regard to the effect of test format.

4.1. Comparing group 1 (school 1) and group 2 (school 2)

While Group 1 received writing instruction using paper and pencil, Group 2 had been using a tablet for the three foregoing months. In this case, it was possible to receive information about the effect of writing instruction tool on early writing outcomes assessed by the paper-and-pencil test. For the *transcription task*, between Group 1 (School 1) and Group 2 (School 2) we found no statistically significant difference for number of words, and share of errors (spelling; other errors). Thus, these results indicate that a three month period of tablet use does not necessarily imply a weakened development in writing speed in a paper-and-pencil test.

For the *dictation task*, we neither found any statistically significant differences in share of errors and number of words written. Notably, this result might partly be due to a ceiling effect, as pupils could maximally write 72 words provided by the dictation text. Thus, the dictation task *per se* sets limitations to such differences.

We also used the number of written words on the *free text task* to measure pupils' writing speed. Note that the validity of this indicator is limited given this young age group. In line with previous findings, we did not find any statistically significant differences in writing speed between the two groups, tested by paper and pencil.

In sum, we found no statistically significant differences between pupils receiving two different writing instruction methods, if both groups used paper and pencil when tested. Notably, both groups had used paper and pencil in grade 1 and grade 2. The findings indicate that tablet use in writing instruction in Group 2 had not caused any differences in early writing outcomes after three months. (See [Appendix 2: Tables 1–3](#) for full results).

4.2. Comparing group 2 (school 2) and group 3 (school 2)

Pupils in Group 2 and Group 3 attended the same school, and their teachers applied the same writing instruction method. Here we used different test formats when testing the effect of writing instruction tools on these pupils' writing. Group 2 received the paper-and-pencil test while the pupils in Group 3 used their tablet computers. For two tasks, transcription and free text, we found statistically significant differences in number of words, in favor of Group 3, indicating an effect of *test format* on the result of such writing tasks. We found that pupils who used tablets when tested wrote far more words than those who tested by paper and pencil. On the transcription task, pupils in Group 2 wrote 32 words ($SD = 9$) on average, while those in Group 3 on average wrote 45 words ($SD = 14$), which means 41 percent more words.

For the *dictation task*, we found only a minimal, non-statistical significant difference in writing speed due to the ceiling effect, while we found a statistically significant difference for the share of 'other writing errors'. Pupils in Group 2 had 26.8 mistakes on average ($SD = 11.8$), while pupils in Group 3 only had an average of 18.7 mistakes ($SD = 7.5$). The lower score of Group 3 might be a result of the digital test format: many of the mistakes made in Group 2 were lack of capitalization at the beginning of sentences. This was not the case for pupils in Group 3, who used a tablet: They started a new sentence by pressing 'Enter'. The line shift caused the program to start the first word with a capital letter. Thus, the share of writing mistakes seems to be associated with test format, rather than related to writing instruction tool. This finding was supported by pupils' statements in group interviews; a couple of the pupils interviewed mentioned the importance of remembering a capital letter in the first word in sentences. (See [Appendix 2: Tables 1–3](#) for full results).

4.3. Comparing group 1 (school 1) and group 3 (school 2)

Group 1 and Group 3 differ with respect to both issues of interest, writing instruction method and test format. Even though they appear to be not comparable in principle, the results reveal some interesting patterns, although not statistically significant. For transcription task and free text task, Group 1 (handwriting), tested by a paper-and-pencil format, showed fewer errors (spelling errors and other writing errors) compared to their counterparts tested by a digital format. At the same time, for dictation, Group 1 did not differ significantly in the number of words written, compared to Group 2 and 3, probably due to a ceiling effect. (See [Appendix 2: Tables 1–3](#) for full results).

4.4. Limitations

With the aim to investigate the effect of writing instruction tool and test-format this pilot study has limitations in terms of its quasi-experimental nature and its cross-sectional approach allowing measurement at only one point in time. A second limitation is associated with the amount of tablet use in the groups. The test was administered at a point in time when pupils in School 2 had used tablets for about three months. Moreover, the pupils in the control group might have had experience from home of using tablets or other digital devices for writing. Hence, we do not know the true difference in the amount of using digital writing tools.

5. Conclusion and implications for a larger effect study

The aim of this pilot study was to develop a study design to investigate the impact of two different writing instruction tools embedded in writing instruction (tablet computer; pen and paper) and to pilot a writing test to measure the effect of these on early writing outcomes among third-graders. In general, from our experience, even with chosen schools from the same school

district, we found differences between the two schools in terms of pupils' home background (socio-demographic characteristics), in favor of School 2 (tablet computer).

Building on our experience from this pilot study, in the concluding section, we will outline some suggestions for the development of a larger effect study ('experiment') by addressing first, the limitations related to the study design and second, the main limitations associated with the writing test. Third, by considering some of the incremental changes in the field of writing instruction we provide some suggestions in terms of scope for a larger scale effect study in the future.

5.1. Implications for a larger effect study

The conduct of an effect study in education with an experimental design on a larger scale is challenging for ethical, methodological and practical reasons. First, one has to weigh up positive consequences related to the study and financial costs and probable disadvantages for participating pupils, teachers and schools. The development and implementation of effect studies means to adhere to strict methodological requirements, for example, a randomized allocation of individual pupils (or classes of pupils) to intervention and control groups, which is difficult to put into practice. Such methodological requirements deal with comparability of different groups and validity and reliability of outcomes. In contrast to medicine, which a longer tradition of clinical studies in the laboratory, in education, effect studies are difficult to implement for practical reasons; pupils are located in classes and daily routines at schools are often characterized by unforeseen events and changing plans. For the implementation of a larger effect study on the effect of digital writing schools in early writing instruction, we consider the following issues as crucial: first, to identify comparable test schools, comparable intervention and control groups; second, to define an appropriate sample size; and third, test implementation.

Choosing different schools, even chosen from the same area, schools might differ in context factors like socio-demographic characteristics. With regard to a future study and the identification of comparable groups using different writing tools, one has to consider probable contamination effects when choosing pupils from the same school, and the risk of choosing pupils for different schools, schools that might differ in context factors, even if located in the same area.

To identify a real test group one needs to find individuals, who were actually exposed to the condition under study over a certain period. This is a challenge according to conditions facing pupils at school. During their school career, for example, pupils switch between different schools or school classes, which might affect pre- and post-test measurements due to changing pupil composition. In terms of implementation, teachers might differ in how they apply and implement for example tablet computers in writing instruction. Thus, to recruit real test groups, one has to keep in mind comparability of student composition.

To conduct an effect study the identification of a comparable control group is mandatory. Thus, one needs to recruit individual pupils or classes of pupils comparable to those in the test group in terms of socio-demographic characteristics and other factors. The identification of a comparable 'control group' is challenging with respect to the non-use of digital writing tools. Children might have had access to digital writing tools such as tablet computers at home (e.g., Neumann, 2016), which is difficult to control. To draw robust conclusions on the effect of a particular writing instruction method (tablet computer) compared with control (handwriting), one needs to recruit relatively large samples from comparable areas (school districts) or large schools. The number of pupils in a sample further depends on the issue under study and the effect size expected. For measurement of complex writing outcomes larger sample sizes are required compared with the measurement of one-dimensional outcomes. Further, with respect to test implementation on a larger scale, one needs to develop standardized test material, test manuals and teacher instruction to ensure implementation of the writing tests in a comparable way across different classes and by different teaching staff.

5.2. Further development of writing test

Our writing test was primarily used to assess writing speed of third graders. As such, only the first task (transcription task) was adequate to assess writing speed. Our reason for including two additional tasks, namely dictation and free writing, was to include and test several dimensions of writing for postponing studies, and to validate the first writing task. Thus, by including dictation and free writing, we could assess several dimensions of early writing, such as spelling, sentence structure and text structure. With respect to a future study, the transcription task proved to be adequate in the present form. The text the pupils received appeared to be long enough even for the fastest writers. The dictation task proved to be a proper way to test pupils' spelling skills. Further, the free writing task seemed to be an adequate way to investigate further dimensions of writing such as grammar, text structure and creativity. Assessment of pupils' essays, however, is more challenging to conduct and requires didactical skills in the discipline.

5.3. Complexity of writing (outcomes)

Considering the rapid changes in the field of writing instruction, a subsequent effect study could raise the question of how to combine handwriting and digital writing instruction to improve pupils' early writing. Against the backdrop that *writing* has been gaining in importance compared with reading (e.g. Berninger et al. 2015) in the 21st century, there is a further need for studies capturing the *complexity* of writing instruction methods and writing outcomes, to investigate the impact of traditional

and 'non-traditional' instruction methods on writing outcomes and writing processes among beginning writers. These studies might investigate several dimensions or forms of writing, such as linear writing and collaborative writing, and address the question of how we can further conceptualize writing outcomes and writing processes for early writers, as such. An example of such a study is that of Åkerfeldt (2014) investigating the interaction between writing condition and writing test layout, for older pupils at the end of grade 9. Åkerfeldt (2014) explored how different resources applied in test situations affect pupils' writing outcomes and processes. One core finding is that new technologies affect pupils' writing process (190) in how they use their time in writing, for keystrokes, editing and pauses. While students in the pen-and-paper condition took more pauses, those in the digital condition using Word program edited their text more frequently. While the former seemed to write according to a linear logic, the latter appear to regard writing rather as a 'composing process' by using the computer screen as a 'tool for thinking' (Åkerfeldt, 2014: 188). The Åkerfeldt (2014) study might have implications for a follow-up study addressing younger pupils in primary education, pupils growing up with tablet computers being already a natural part in early literacy socialization. What are the differences in writing outcomes and writing processes between pupils who apply either pen-and-paper or digital tools during their first phase in writing instruction? Do they differ in their motivation in terms of writing dependent on the method applied in the first phase? If digital writing has already become the norm in adult life, while handwriting appears to lose ground, at least in working life and at university, what makes handwriting unique, and why is it still important in the digital age? Even though writing has become more 'diversified' in line with digitalization, we agree with Santangelo and Graham (2015) that handwriting is still a frequent and useful tool, particularly in primary and secondary education.

Proponents of using digital writing tools in early writing instruction argue that in particular struggling writers with poorly developed fine-motor skills gain an advantage in writing instruction by tablet computers, which appear easier to handle than pen-and-paper devices. Research on the impact of so-called 'hybrid writing tools' that combine the advantages of traditional writing tools with those of new technologies, such as electronic pens, however, is scarce. One exception is the study by Vinter and Chartrel (2010), that investigated the impact of 'hybrid' writing tools combining traditional writing tools and new technologies, such as electronic pens. Synthesizing the impact of using technology as part of handwriting instruction Santangelo and Graham (2015) identified positive and statistically significant effects for legibility.

A third study by Jones (2015) combines two theoretical perspectives, the cognitive theory of writing and the socio-cultural theory of writing, and applies a pretest-posttest control group design investigating the impact of three writing instruction methods – writing workshops, interactive writing, and traditional writing instruction control groups – on 5-year old kindergarten pupils. Writing workshops consisted of daily mini-writing lessons, student writing time, conferencing and sharing, to teach students individually to create a variety of different texts and genres over a whole year. Finally, students shared their work informally in small group discussions and formally during 'author's chair time'. Students used a variety of tools such as pencils, pens and paper. In contrast, interactive writing lessons were organized in a way for teacher and students to produce texts of varied length, while they were gathered for group instruction. During the year, the teacher gave explanations and opened for thinking aloud to show the processes and procedures of writing. Pupils in the control group received traditional writing instruction with emphasis on correct spelling. Tools mentioned by the study author were e.g., pens and paper, but no digital tools. For foundational writing skills, no significant differences were found between the three methods; for compositional writing skills, however, both groups, those in the writing workshop group and those in the interactive writing group, outperformed students in the control group, while no significant difference was found between the two intervention groups. The author concludes first, that a writing-rich environment is crucial for students to develop compositional writing skills; second, that teacher explanations, thinking-aloud methods, and modeling are important in effective writing instruction; third, is the need for students to get used to the writing process that comprises writing and revising; and fourth, the need to create a community of writers, providing importance of the environment and participation in discussions on text composition between students and professional teachers (Jones, 2015).

In sum, building on our pilot study, a larger effect study might incorporate some of the issues raised above, for example a third instruction method applying hybrid writing tools, and thus compare the impact of three different writing instruction methods on different early writing outcomes and writing processes.

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Appendix 1. Writing test (English translation)

This is an English translation of the writing test from Norwegian.

Implementation of writing test - instruction for class teachers

1. Please check that all pupils have returned the letter of consent given signed by their parents.

2. Please tell your pupils that the writing test has three parts: transcription, dictation and free writing.
3. Please check that all pupils have access to paper and pencil and eraser and tablet computer.
4. Pupils will get a writing book for the writing test.
5. Please make clear that this NOT a test in one's best handwriting, but tell the pupils that they still have to write legibly and have to remember lowercase and uppercase letter.

Part 1: Transcription

1. Pass the writing test and the form with the story, 'The Fox and the Bear' upside down. Tell pupils not to turn the page before you ask them.
2. Ask pupils to open the first side of the writing book, and tell them about the text to transcribe on a loose writing form. Ask them to transcribe the text as quickly and as correctly as possible, but tell them that it is possible that they will not be finished but that it is ok to write as much as they can.
3. Tell pupils that they can start counting words after 7 min.
4. After 7 min, please ask pupils to stop and collect the loose writing form with the story.

Part 2: Dictation

1. Ask pupils to turn the pages in their writing book up to part two, where lines are numbered from 1 to 10.
2. Tell pupils that a) you will read 10 sentences, b) that you will read each sentence twice, and tell them that you will give them 30 s to write each sentence. They will be allowed to start while you read; d) after 30 s, start to read a new sentence.
3. Use an appropriate watch to make it easy to control number of seconds.
4. Be sure that your pupils understand the task and start reading.
5. Provide them exactly 30 s to write.
6. Start reading the next sentence, right after 30 s.
7. After sentence 10 and the following 30 s, ask pupils to put aside writing tools.

Part 3: Freewriting

1. Ask the pupils to turn the pages in their writing book up to the page with the headline – "Finally Christmas"
2. Tell them that they should write a story about Christmas or winter. They might also write several small stories, if they finish earlier than their time schedule (7 min).
3. After 7 min, ask pupils to put aside writing tools and collect writing books.

Part 1: Transcription task: «The Bear and the Fox»

Once upon a time, there was a bear and a fox who jointly owned some fields. They had a small growing plot in the woods, and the first year they sowed rye. The fox said: "Now, we share it right. Would you like the roots, I'll take the top." The bear agreed. After they had shared, however, the fox got the grain and the bear nothing but bugs. The bear did not like that, but the fox said that this was their agreement. The fox suggested they could switch the next year so that the bear would get the top and the fox the bottom. But when spring was coming the fox asked the bear to think about turnips. The bear thought turnips were cheaper than corn, and the fox agreed. When the autumn came, the fox took the turnips and the bear got cabbage. Finally, the bear became so angry that he went apart with the fox immediately.

Part 2: Dictation «Holidays»

1. In a week's time, there are holidays.
2. Then, Tore will go on a trip with daddy.
3. They are going to take the boat to Denmark.
4. Mummy will help Tore to get ready.
5. The luggage became very heavy.
6. Tore has difficulty in carrying the baggage.
7. They shall buy some food on their way.
8. Tore hopes that he can eat a lot of ice cream.
9. He has heard that ice cream tastes different there.
10. Ice cream will taste good anyway.

Appendix 2. Tables 1–3

Table 1
Transcription task – number of words, spelling errors and other writing errors.

Group	Test	Words		Spelling errors		Other writing errors	
		M	SD	M	SD	M	SD
Group 1 (n = 15)	Paper	33	13	4.1	5.0	6.9	8.8
Group 2 (n = 14)	Paper	32*	9	5.7	5.9	10.5	11.0
Group 3 (n = 18)	Tablet	45*	14	6.0	4.5	7.8	5.7

*Significant differences, $p < 0.05$. To give a reminder Group 2 and Group 3 belong to the same school, School 2.

Table 2
Dictation task – number of words, spelling errors and other writing errors.

Group	Test	Words		Spelling errors		Other writing errors	
		M	SD	M	SD	M	SD
Group 1 (n = 15)	Paper	60	9	16.5	7.5	22.6	11.3
Group 2 (n = 14)	Paper	64	12	19.6	7.2	26.8*	11.8
Group 3 (n = 18)	Tablet	68	7	16.8	6.4	18.7*	7.5

*Significant differences, $p < 0.05$.

Table 3
Free text task – number of words, spelling errors and other writing errors.

Group	Test	Words		Spelling errors		Other writing errors	
		M	SD	M	SD	M	SD
Group 1 (n = 15)	Paper	42	11	11.3	6.9	17.5	8.4
Group 2 (n = 14)	Paper	48*	19	13.8	7.6	21.2	9.4
Group 3 (n = 18)	Tablet	63*	19	14.4	8.3	18.7	8.8

*Significant differences, $p < 0.05$.

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