

Exploring the Potential of Digital Pen Technologies for Learning Handwriting

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ABSTRACT

Today's classrooms rely on many technologies to aid learning, yet handwriting is still largely taught using traditional methods and tools: such as using pencil and paper to complete writing exercises. As technology progresses in everyday and work life, and computers, like PCs and direct-touch tablets, find their way into the classroom, it is likely that the way we learn to handwrite at school will begin to include some form of digital enhancement. My research investigates ways and consequences of facilitating handwriting learning through digital pen technologies by (1) evaluating the influence of existing pen technologies on childrens writing experience and handwriting quality and (2) designing potential writing applications that can support childrens handwriting learning through different feedback mechanisms. I have completed two years of my doctoral studies and I am looking for feedback on my research; particularly my research questions, methods and intended contributions. Attending the doctoral colloquium will provide an opportunity to evaluate my work to date and focus my future studies and help to structure and finalize my research.

Author Keywords

Handwriting; digital handwriting tools; evaluation; child-computer interaction; children; learning technologies

ACM Classification Keywords

H.5.m. Information Interfaces and Presentation (e.g. HCI); Miscellaneous; K.3.1. Computer Uses in Education: Computer Assisted Instruction(CAI)

INTRODUCTION

The goal of my research is to explore the potential role of digital writing tools during childrens handwriting learning processes. The presence of digital technology within classrooms and learning environments is becoming more commonplace yet handwriting, an essential lifelong skill and a key component of education, is still largely taught using regular pencil

and paper. Learning to handwrite using traditional methods provides educational benefits such as improved letter recognition, phonological associations and compositional skills [4, 3, 5, 8]. However, digital technology offers advantages that build on traditional approaches to enhance classroom activities. For example, incorporating haptic feedback using a Phantom device (a robotic arm with a pen), when handwriting helped children improve their letter recognition and phonological awareness [1, 7]. It has also been shown that augmenting pen and paper interaction using projection during geometry [2] or calculus [13] can facilitate learning. Furthermore, studies have investigated using digital writing tools in combination with handwriting recognition software for text entry and digitisation [9, 10, 12]. In addition, it is now possible to access information such as pressure, tilt, and pen angle during handwriting [14], which opens up new possibilities for future pen applications.

Existing digital writing tools, which can be categorised as 'pen-on-paper' or 'pen-on-screen', are commercially available and often marketed as useful learning aids. For example, Livescribe¹ and LeapFrog² both sell Anoto³ based 'pen-on-paper' technology. LeapFrog in particular markets with a focus on early years' literacy skills, including handwriting. Recent years have also seen an increasing availability of educational tablet-based applications targeting the writing skills of young children, for example, ABC Cursive Writing⁴, and iCanWrite⁵.

It is likely that interest in digital pen technology in educational environments will increase over time and that learning handwriting at school will include some form of digital enhancement. In this context, my research aims to contribute to the design and evaluation of digital handwriting tools that will combine digital technology with the benefits and mechanisms of traditional handwriting learning tools. In particular, I focus on the following research questions:

1. How do existing digital pen technologies affect children's handwriting experience and quality?

¹<http://www.livescribe.com/uk/>

²<http://www.leapfrog.com/en-gb/new-home.html>

³<http://uk.anoto.com/>

⁴<https://itunes.apple.com/us/app/abc-cursive-writing/id311406975?mt=8>

⁵<https://itunes.apple.com/us/app/icanwrite/id304080958?mt=8>

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Figure 1: Digital Pen Technologies used in Study.

2. How can digital pen technologies facilitate children's handwriting learning process?
3. How can we adapt existing digital pen technologies to support children's handwriting learning process?

My research addresses these questions (1) by studying children completing handwriting exercises in a classroom setting using different traditional and digital writing tools, (2) through participatory workshops where children are invited to contribute their own ideas toward handwriting technologies of the future, and (3) through an iterative design process where different low-fidelity handwriting prototypes are created and evaluated. The contribution of my research will consist of

- In-depth insights of how handwriting quality can be influenced by different types of digital pen technologies (e.g., contrasting 'pen-on-paper' technology with 'pen-on-display' tools).
- A definition of the design space around digital pen technology in the context of handwriting learning.
- A number of novel digital handwriting tools that can facilitate the handwriting learning process by providing different types of feedback.
- A discussion of challenges and methodologies on how to study children's use of technology and how to engage them in technology design processes.

RESEARCH STUDIES

During the past two years, I have conducted research into the area of teaching and learning handwriting, and explored currently available digital handwriting technologies. To progress my research I have conducted studies with children, to evaluate the suitability of these technologies and begun to explore future directions for how digital pen technologies can support the handwriting learning process. Most recently, I have conducted a study to evaluate the potential implication of using visual feedback to improve children's handwriting. The following outlines my work to date and my future research intentions as I move towards the final stage of my PhD.

Evaluating Existing Digital Pen Technologies

In order to address my first research question, I conducted studies at two different primary schools. As part of the studies, children were asked to complete brief handwriting exercises using different digital pen technologies from both the

'pen on paper' and 'pen on display' categories (see Figure 1). During an initial exploratory study (13 children; 9–10 years old), children wrote with an iPad 2⁶ and stylus, a Wacom Cintiq⁷, a Livescribe Digital Pen⁸, as well as a common school pencil. A follow-up study included 28 participants (again aged 9–10) and the iPad 2 was replaced by a Microsoft Surface Pro⁹, which is designed to be more suited to pen-on-screen use¹⁰. Additionally, the Livescribe pen was substituted by an Anoto ADP301¹¹, bluetooth enabled pen, allowing live streaming of pen data to a local computer during the study. During the study, children were interviewed about their writing experience, perceived handwriting quality, and preferences for each device. Interviews were designed with the age group in mind and children were encouraged to use visual aids (see Figure 5), such as the smile-o-meter [11], to help them provide an answer. Following the study, some of the children's handwriting samples were evaluated by two teachers (both experts in teaching handwriting) to analyse changes to handwriting quality and the contributory aesthetic factors of 'good' handwriting.

The studies have shown that both the Wacom and Anoto technology performed well during the handwriting exercises, both in terms of handwriting quality (as evaluated by the children and teachers) and handwriting experience (as described by the children). In contrast both the iPad 2 and Mi-

⁶<http://store.apple.com/us/buy-ipad/ipad2>

⁷http://www.wacom.eu/_bib_user/dealer/bro_c12_en.pdf

⁸<http://www.livescribe.com/en-us/smартpen/echo/>

⁹<http://www.microsoft.com/surface/en-us/support/surface-pro-specs>

¹⁰<http://www.microsoft.com/surface/en-us/support/touch-mouse-and-search/surface-pen>

¹¹<http://www2.anoto.com/digital-pens-1.aspx>



Figure 2: Children were asked to write using different devices and used visual aids to report on experience.



Figure 3: The iPad influenced children's writing posture and pen grip.

crosoft Surface Pro, performed poorly in comparison to the other tools. As described in [6], this is due to the degradation in handwriting quality caused by poor writing posture to accommodate the touch sensitive, slippery writing surface (shown in Figure 4). However, their increasing prevalence in classrooms, their comparative low cost, ease of mobility, and multi-functionality means that they cannot be completely discounted as potential writing tools in schools in the future.

Exploring Visual Feedback During Handwriting

Digital pen technology has the capability to sense physical information about writing style during the writing process (e.g., pen location, pen tilt, writing pressure, and pen angle). This data can be used to provide feedback to children as they write to improve, e.g., their physical hand posture, letter formation, or letter arrangement. The development of digital writing tools that provides feedback, raises new questions, i.e., (1) which handwriting features to provide feedback on, (2) when to provide the feedback, and (3) what type of feedback is appropriate as outlined in [6]. In order to answer these questions, and inform future work, I have carried out a study where 32 children (aged 8–9), were provided with two paper copies of a handwriting sample, one of which had been altered to include visual feedback. The visual feedback added to the samples was based on the teachers' analysis from an earlier study described above and is shown in Figure 5. The type of visual feedback can be categorized into two groups: feedback similar to what is provided by teachers (e.g., a red pen to underline or circle letters or words or different colours to highlight, underline or encircle areas of text) and feedback that requires digital pen technology (e.g., modify and improve the original text and indicate where this had occurred). Children were asked to report a handwriting quality score for a handwriting sample without and then with visual feedback. The results of the study demonstrate that children's perception of handwriting quality can be influenced by visual feedback and that different types of visual feedback can illicit different degrees of response. This initial study forms the foundation for a more in-depth design exploration on how digital handwriting tools can provide feedback during the handwriting process, which I am currently working on.

RESEARCH STATUS

Currently I am preparing two further studies. One of which is a creative workshop where children will be invited to design their 'pen of the future', over the course of one session. This participatory approach will directly inform my own design iterations. The other involves a year long study with children

Alice was beginning to get very tired of sitting by her sister on the bank, and of having nothing to do. Once or twice she had peeped into the book her Sister was reading, but it had no pictures or conversations in it.

(a) Baseline handwriting sample

Alice was beginning to get very tired of sitting by her sister on the bank, and of having nothing to do. Once or twice she had peeped into the book her Sister was reading, but it had no pictures or conversations in it.

(b) Sample with visual feedback like a teacher (basic)

Alice was beginning to get very tired of sitting by her sister on the bank, and of having nothing to do. Once or twice she had peeped into the book her Sister was reading, but it had no pictures or conversations in it.

(c) Sample with visual feedback like a teacher (advanced)

Alice was beginning to get very tired of sitting by her sister on the bank, and of having nothing to do. Once or twice she had peeped into the book her Sister was reading, but it had no pictures or conversations in it.

(d) Sample with visual feedback

Figure 4: Children were asked to rate two handwriting samples: the baseline and one with visual feedback

in a primary school where tablets are to be introduced as part of the curriculum. I intend to conduct observations in their classroom, for a full week during each term this school year. During this time, I aim to investigate the long term effects of this technology in schools, in general as well as retaining an interest towards handwriting. Additionally, I am exploring different design possibilities for integrating feedback into existing digital pen technologies. As part of this, I am creating a large number of paper prototypes that will be narrowed down and refined to 3 or 4 low-fidelity prototypes. Over the next year I will evaluate these prototypes by inviting children to participate in a focus group style session.

This doctoral colloquium will provide me with an opportunity to learn about the research approaches of other PhD students and the challenges they are facing. I hope to get feedback from other researchers on my own research questions, research methods, and intended contributions. I am particularly keen on critically discussing my approach to designing novel feedback mechanisms to facilitate handwriting learning. I am just starting the third and final year of my PhD, and I would like to use the guidance from the doctoral colloquium to inform and focus my future studies and help to structure and finalize my research.

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