Children's Creativity Lab: Creating a 'Pen of the Future'

Anne-Marie Mann, Uta Hinrichs and Aaron Quigley
SACHI Group,
School of Computer Science,
University of St Andrews, Scotland
{am998, uh3, aquigley}@st-andrews.ac.uk

ABSTRACT

Technology is changing the way we acquire new skills and proficiencies and handwriting is no exception to this. However, while some technological advancements exist in this area, the question of how we can digitally enhance the process of learning handwriting remains under-explored. Being immersed in this process on an everyday basis, we believe that school aged children can provide valuable ideas and insights into the design of future writing tools for learners developing their (hand)writing skills. As end-users of the proposed technology, we explore including children in a form of informed participatory design during a creativity lab where we invited 12 children, aged 11–12, to put themselves into the shoes of a product designers and create a *Pen of the Future* using prototyping materials. In this paper we describe our methodology and discuss the design ideas that children came up with and how these may inform the design of future writing tools.

Author Keywords

Child-Computer Interaction; participatory design; children; handwriting technologies; ideation

ACM Classification Keywords

H.5.2. Information Interfaces and Presentation: User Interfaces - User-centered design; K.3.1. Computer Uses in Education: Computer Assisted Instruction (CAI)

INTRODUCTION

Technology is integrated into our daily lives including work- and spare time activities. From a very young age, children are exposed to more technology than ever while acquiring the skills and knowledge expected in the modern world [3]. However, some foundational skills, such as handwriting, have remained largely untouched by the digital revolution. As technology progresses, it is likely that learning handwriting at school will include some form of digital enhancement, but the research, design, development and evaluation of such tools have yet to be fully explored.

ACE '14 Workshops, November 11 - 14 2014, Funchal, Portugal

ACM 978-1-4503-3314-6/14/11$15.00
http://dx.doi.org/10.1145/2693787.2693805

Digital handwriting technology has already been successfully applied in educational settings [2, 4, 18]. For example, introducing haptic feedback during handwriting has been found to improve letter recognition and phonological awareness in children [2, 15]. Furthermore, studies have investigated using digital writing tools with handwriting recognition software for text entry and digitisation [17, 18, 20]. In the context of teaching mathematics, it has been shown that augmenting pen and paper using digital projection can help the understanding of geometry [4] and facilitate learning by providing calculus functionality [25]. In addition, the suitability of using different handheld devices in classrooms for writing [13] or when solving maths problems has also been investigated [14, 24]. Previous work highlights the potential of digital writing tools in educational contexts, however, a writing tool with potential widespread use in schools has yet to be fully designed and specified. Furthermore, research has shown that adults and children perform differently when using technology, for example, when using touch and pen gestures [1]. The design of digital handwriting tools will require investigations into the requirements, in terms of functionality, suitability, and appeal for children while learning.

With the design and evaluation of technology aimed at children, it is increasingly common to include them in the design process. Children have acted as design partners [10], participated in usability studies [7, 19] and workshops [12, 16, 23] and have provided feedback on the use of design probes [21, 26]. Participation in such activities is an opportunity for researchers who get to collect direct qualitative feedback from their target user group [11] and for children to learn, be creative, and inform the design of future educational products that are both effective and fun to use.

Our Children's Creativity Lab, as a form of participatory design workshop, invited children to be creative in helping solve a contemporary design problem relevant to their everyday life. The exploratory activities that we offered as part of the Lab introduced children to the capabilities of current available handwriting technology (e.g., Anoto pens[1] and Wacom tablets[2]) and asked them to consider which features they would find appealing as part of a *Pen of the Future*. By the end of the workshop, children had created a model of their pen, using prototyping materials e.g., plasticine, card stock, and colour pens (see Figure 1). The design and development

[1] http://uk.anoto.com/
[2] http://www.wacom.com

Figure 1: Pens, pencils, crayons, coloured paper, and plasticine used to create low-fidelity prototypes.

of these models introduced children to creative design processes in an accessible way, using vocabulary and materials suitable for children, and provided us as researchers useful insights about the children's take on digital handwriting tools to inform the design of handwriting technology that we intend to build in the future.

INCLUDING CHILDREN IN DESIGN ACTIVITIES

Children can be included, to different extents, at different stages of the design process. Typically, children's participation can take the form of one of four recognised roles: user, tester, informant and design partner [8]. This role is determined by many factors, usually as a balance between the best approach, time and resources. During our Children's Creativity Lab, we asked children to become a *design partner* for the duration of the Lab session.

As design partners, children are involved in the entire design process of new technology [8]. Such an involvement can be short or long-term and include participatory design and co-operative inquiry [8, 11]. Participatory design is based on researchers and child participants working alongside each other during a design task. This approach allows children to apply their insights and own experience to a project in a school-like environment, where everyone benefits from mutual learning [11]. A more recently developed theory, co-operative inquiry, places emphasis on the inclusion of children as full design partners: where they conduct field research and undergo training in order to iteratively create low-tech and high-tech prototypes [8]. In our Creativity Lab, children were treated as design partners for the duration of the lab session.

Participatory Design in a Workshop Environment

Scheduled workshops such as our Creativity Lab provide opportunities to temporarily get children involved in the design process. The setup of the workshop can offer a lot of flexibility: tasks can be very specific or more open-ended, time commitment can vary from a few hours [23], to months [5] or even years [16]. Participants can work individually, in pairs [23] or as part of a larger group [27]. Deciding which workshop approach to take requires finding a balance between time constraints, and resources.

CREATING A PEN OF THE FUTURE

During our Creativity Lab, as outlined below, we complete a mini design process. Our approach, that drew from the theories of co-operative inquiry, and participatory design applied them in a condensed session. Over the course of the workshop children were guided through the design process in small tasks: learning about handwriting assessment, digital writing technologies, and applying their knowledge to solve a design problem. Each section of the workshop is delivered in a way that is both suitable and enjoyable for children e.g., using appropriate language, encouraging participation with each other, and using familiar craft materials. By presenting the workshop as a series of small sub-tasks the activity becomes more easily achievable whilst also allowing children to benefit from a relaxed but engaging environment. Our Creativity Lab was organised and conducted as a part of the Advances in Computer Entertainment Technology 2014 (ACE'14) conference workshops. We document the process and outcome here in the hope that the findings will inform the design of future writing tools aimed for classroom contexts.

Participation

We invited 12 children (5 boys), aged 11–12, from a local high school to take part in our Creativity Lab. In contrast to younger children, children of this age are able to understand and to participate in the activity of the Creativity Lab. Furthermore, with long-term first-hand experience in handwriting, they can provide their opinions about handwriting and how they feel this can be improved using digital technology. Children were asked to work in groups of two to three. We hoped that working in groups would encourage them to actively participate in the session and to actively develop and discuss a large range of ideas. The session was conducted by one of the authors with the help of two native Portuguese facilitators (Portuguese was the children's native language).

Over the course of the session children were introduced to current off-the-shelf handwriting technology such as tablets and Anoto pens, and were introduced to the functionality of different hardware that may be included into a digital handwriting tool (e.g., pressure and tilt sensors, cameras, etc.). To keep the children engaged in the project, they participated in hands-on activities, and were asked to step into the shoes of a designer, creating a prototype using various prototyping materials.

Creativity Lab Setup & Procedure

The *Pen of the Future* Creativity Lab session was designed to be a fun, engaging, educational, and creative activity for children. During the session children were guided by enthusiastic facilitators as they participated in interesting short sub-activities that built towards the final aim of the workshop:

(a) Sketch of Concept (b) Low-Fidelity Prototype (c) Flower Pen (d) Final Product

Figure 2: The design of an aesthetic pen holder from concept, to prototype to final product.

becoming a designer to make a *Pen of the Future* prototype. By dividing the lab session into four small activities, children were guided through the design process in achievable steps. The Creativity Lab was conducted in one of the school classrooms, that had a whiteboard and projector available for use. Each step of the session (which lasted less than two hours in total), was documented using photographs and video.

Brainstorming: What makes 'good' handwriting?

In order to get children in the right mindset, the first session of the day, which lasted 10 minutes, invited them to brainstorm features that make for 'good' handwriting. To encourage an open atmosphere, facilitators introduced themselves using their first name and used a light, conversational tone with the children. All children were asked to brainstorm together as a group by shouting out their suggestions and these were discussed and explained before being displayed, on a whiteboard, which was visible to all the participants during the session (see Figure 4(a)&(b)). In addition to aesthetics, children were asked to also consider the physical skills required to be a good writer e.g., fine-motor control skills to hold the pencil, and good hand–eye coordination. To aid the discussion, the facilitators had access to a list of factors that have been found to be relevant for good handwriting e.g., legibility of characters, consistent sizing, and correct spacing between words and characters [6, 9, 22]. As a result, the facilitator was able to prompt the discussion towards any relevant factors which may not have been suggested by the children themselves. At the end of the exercise, a slide with a list of the relevant features of handwriting was shown and discussed. This brief activity was designed to encourage a fun, inclusive, and friendly atmosphere and children were praised for their contribution and participation. In addition, children were introduced to the vocabulary and concepts that were helpful during the subsequent activity where they were asked to evaluate handwriting samples.

Evaluating Handwriting Samples

During the second task, which lasted 25 minutes, children were asked to apply their newly acquired knowledge to evaluate handwriting samples. Again as a group, all children were shown a handwriting sample (see Figure 3), via projection, and asked to assess it using the vocabulary gained during the previous task. Facilitators asked children to shout out their opinions of the handwriting. This was repeated once more; encouraging children to decide if the samples are good or bad and to explain their opinions to the class. To make the activity more fun, children were asked to guess the writing tool (pencil, pen or crayon), who wrote the sample (boy, girl, man or woman) and other details like this. This consolidated children's learning as well as increased their confidence in the activity.

Now, as accomplished handwriting 'experts', the children were asked to work in groups of two or three to assess a handwriting sample. This approach helped to foster creativity and discussion among all participants. Children were provided with pens and asked to annotate the handwriting sample they have been given; showing what they thought were good or bad qualities (see Figures 5). By the end of this activity children had acquired a firm grasp of what constitutes good handwriting. The following task introduced them to the potential capabilities of technology to improve the handwriting process and quality.

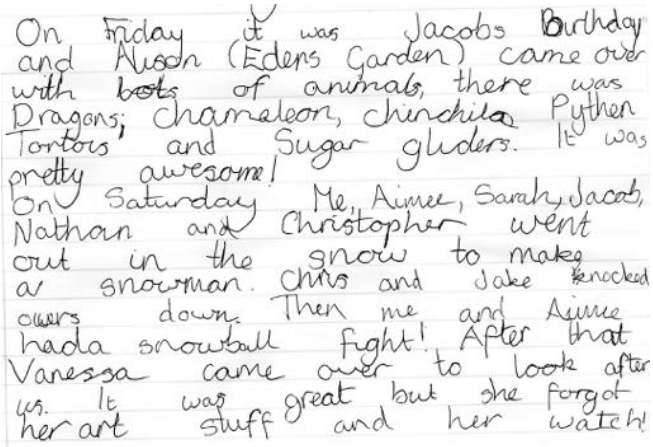


Figure 3: This handwriting sample was projected and assessed by participants as a group.

(a) (b) (c) (d)

Figure 4: The children took part in brainstorming (a), discussion (b), picked materials (c), and presented their prototype (d).

Technology and Prototyping

In order to inspire and inform the group, the facilitator spent 15 minutes introducing digital pens that are currently available on the market (i.e., tablet and stylus, Anoto pens, and graphics tablets). Also, other more futuristic pen examples have more unusual qualities (i.e., projectors, speakers, and robotic arms). The facilitator described, using language suitable for children, how these digital pens work and the kind of information they can gather from writers. Where possible, video footage, images and/or the actual device was shown. At the end of the session children were shown videos of different digital pens in action. As part of this, digital data that such pens can gather were shown and the concept of sensors and actuators was introduced.

The facilitator explained that during the design process for new products, sketches and prototypes are prepared using low-fidelity prototyping materials such as paper, plasticine, or sketches. To support this claim, images of design sketches and prototypes were shown, see Figure 2. This introduced prototyping as a step in the design process in an accessible way, allowing the children to ease into the role of designers whilst sparking ideas for the final activity.

Maker Session

During the final and main activity of the creativity lab session, we invited children to form groups of two or three and allocated 1 hour for them to design and prototype a *Pen of the Future*. In this activity children were able to generate ideas about what kind of pen they would like to use in the future, using the knowledge and concepts acquired from previous sessions about handwriting and hardware components. Children were encouraged to think about form and function of the pen, and to consider aspects such as physical comfort as well as novel functionality in their design. Ideas could include features that would help them improve their handwriting but could also go in a more futuristic directions. Children had different means to flesh out their ideas: they could create paper sketches, or model the pen using plasticine, straws or other materials that were provided. They were encouraged to pick whatever material they felt most comfortable and creative with (see Figure 4(c)). We found that most of the children were enthusiastic and wanted to create their own prototypes, which we did not prevent. As a result, ten children worked individually while two worked as a pair. During the activity, the facilitators asked children about their work and ideas in a relaxed manner: children were encouraged enjoy the activity by being creative, developing their ideas and having fun with the materials. At the end of this session each group was invited to present and describe their prototype with all its (imaginary) functionalities as part of a design critique where each child was asked about their design and thanked for their participation. These presentations, which lasted about 10 minutes, were video recorded. All of the prototypes and sketches were photographed for further analysis (see Figures 6 for examples).

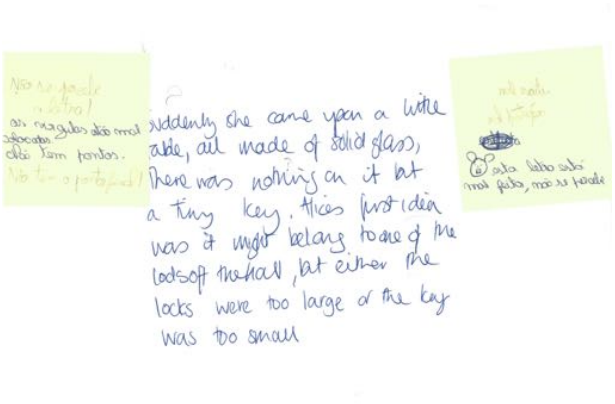
FINDINGS

During the Creativity Lab, children were engaged, actively participated and used their knowledge and personal experience to prototype their *Pen of the Future*. In the following, we discuss the results of the individual workshop activities, in particular the artifacts that were created during the prototyping session (see Figure 6).

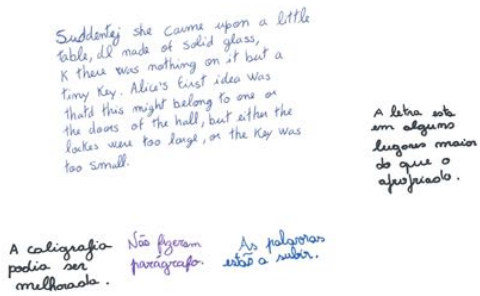
Brainstorming, Handwriting Evaluation & Technology

Prior to the *Maker Session*, children took part in small sub activities designed to encourage them to think about what characterizes 'good' handwriting and how technology can be involved in the handwriting process. Children were highly engaged in these first three activities, visible in vivid discussions (see Figure 4(a) & (b)). Additionally children's responses, such as *"the way how we hold the pen"* and *"to write on lines"* and *"to write in a legible way"*, were similar to the responses we expected in terms of how to judge handwriting quality.

As a group, children were asked to evaluate handwriting samples written in English (ignoring the content of the text) that were shown using a projector. The children were asked to consider the context of the writing as well as its presentation. Speculation of one handwriting sample (as shown in Figure 3), included comments such as *"it's not readable"* and *"looks like my father's handwriting"* and *"it looks as though it was written by an adult because it looks as if it was written in a hurry"*. The subsequent evaluation session in small groups showed that children were capable of assessing handwriting samples in a complete and confident way. Methods of annotation varied between groups: some used post-its, others



(a) Some groups annotated handwriting samples using post its.



(b) Some annotations of handwriting used different colours.

Figure 5: Children assessed and commented on handwriting samples in pairs.

directly annotated the text sample, sometimes using different colours (see Figures 5(a)&(b)).

During the *Technology and Prototyping* session children were engaged by the discussions and videos of current pen technologies. They understood that there are already some pen technologies that 'know' what is written down, i.e., the capability of some pens to capture and turn handwritten notes into typed text. Similarly, children had a good grasp of the process of prototyping, visible in comments such as: *"a prototype is a scheme of what we want to build"* and *"a prototype is something we make to do tests"*.

Building their design

The children were excited about creating their own *Pen of the Future*. One child remarked *"to make the pen is better than writing"*. As mentioned earlier, whilst asked to work together in small groups, ten of the children opted to work individually - each child chose their prototyping materials from a table at the front of the class (see Figure 4(c)). Children had around one hour to complete their design, annotate and present it (see Figure 4(d)). Below we outline the children's designs, which can be seen in Figure 6. The features included in the final prototypes can be categorized into *futuristic qualities* and *aesthetic qualities*.

Futuristic Qualities

Of the eleven *Pen of the Future* prototypes, eight have what we call 'futuristic' qualities, that is, qualities that go beyond the capabilities of current technology. Six designs included features such as the ability of the pen to write or erase by itself (see Figure 6(a),(b),(d),(e),(g)&(i)). Four designs featured functionalities to automatically complete homework or exams (see Figures 6(e),(f),(i)&(j)) either through dictation or through inherent 'knowing'. Four of the children's designs incorporated some kind of translation property - the ability to write in different languages (see Figures 6(a),(d),(g)&(j)).

Two of the designs considered the concept of writing speed into their design. For example, one included a simple clock with a timer function that displayed the time you had spent writing (see Figure 6(c)). Another, featured a more futuristic capability to select the speed of the users handwriting (see Figure 6(b)). Of all the designs, only one pen considered the handwriting quality - the ability to select the kind of quality of handwriting (see Figure 6(b)).

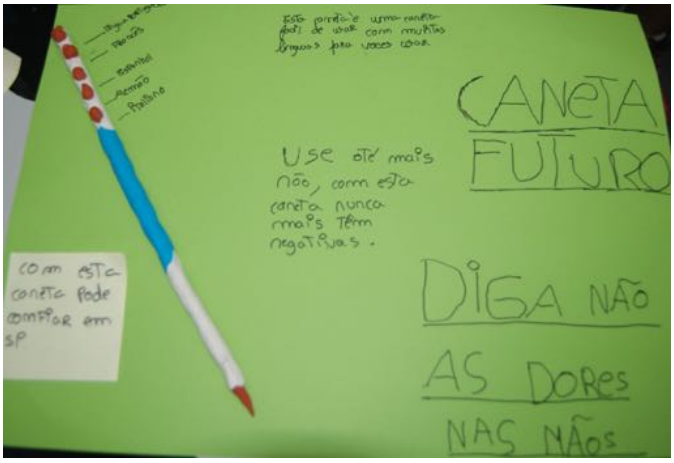
Aesthetic Qualities

All of the children enjoyed the process of creating their prototype, and all presented the design of their pen with enthusiasm. Some of the children named their design such as "Mimosa", "Bolonix", "Time Pen", and "Expert", (see Figures 6(f),(j),(c)&(g) in that order). Three children described the potential cost of the pen (see Figure 6(b)(i)&(j)) after production (2–5 Euro).

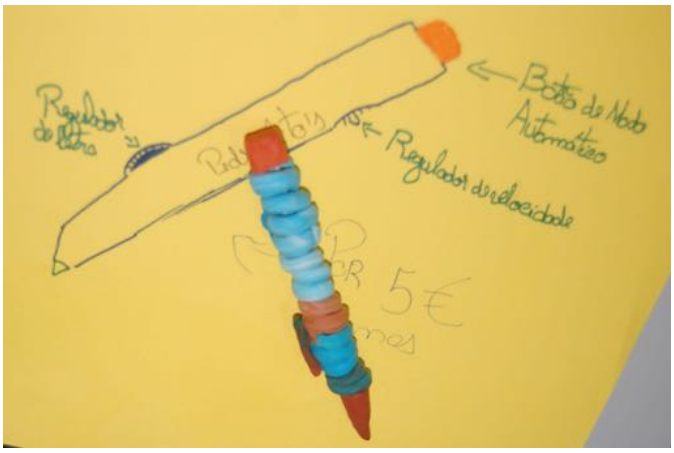
Children used colours to help make their designs more attractive, or add buttons for functionality (see Figures 6(a),(b)&(c)). When presenting their designs to the group, five children mentioned particular design aspects. Of all the prototypes, only one pen design focused solely on the form and ignored any extra functionality– this pens special feature was the capability to customise and modify itself according to its user's preferences (see Figure 6(h)). In other designs, the incorporation of Portuguese colours (see Figure 6(d)), glitter ink (see Figure 6(f))and a spiral microphone (see Figure 6(g)) demonstrated that the children had given thought to the aesthetic qualities, in particular the form and visual appearance of their prototype design.

DISCUSSION

When asked to evaluate the Creativity Lab session all children reported that they enjoyed the activities. The incorporation of the earlier sections helped children to get used to the workshop environment, the other children and to become confident with the topic. However, the training that children received in handwriting evaluation early on in the workshop appeared to have little influence on the prototypes they produced. The resultant pen designs from the workshop raise some interesting



(a) Prototype with buttons for language functions and auto-writing.

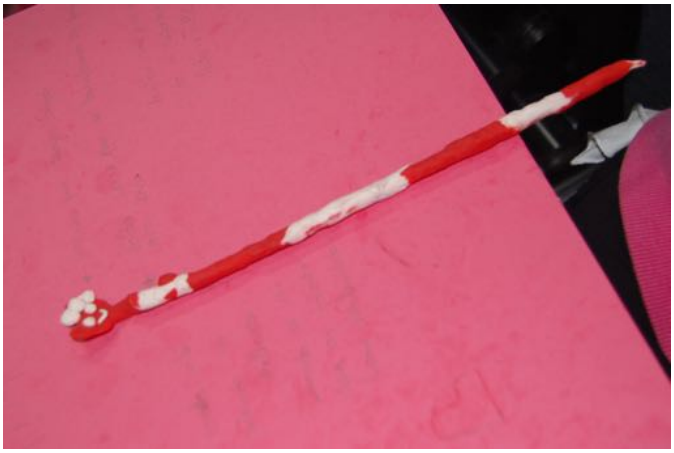


(b) Prototype has buttons to select writing speed and costs 5 Euro.

(c) The‘Timepen’ uses a simple timer.

(d) Pen has colours of Portuguese flag, and language functionality.

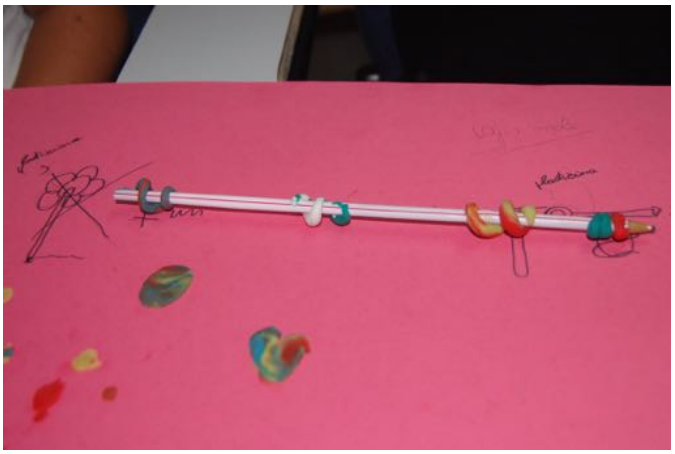
(e) This pen writes itself to compete homework and exams.



(f) The ‘Mimosa’ pen completes homework in glitter ink.

Figure 6: The children’s prototype ‘Pen of the Future’ were presented to the group (cont. on next page).

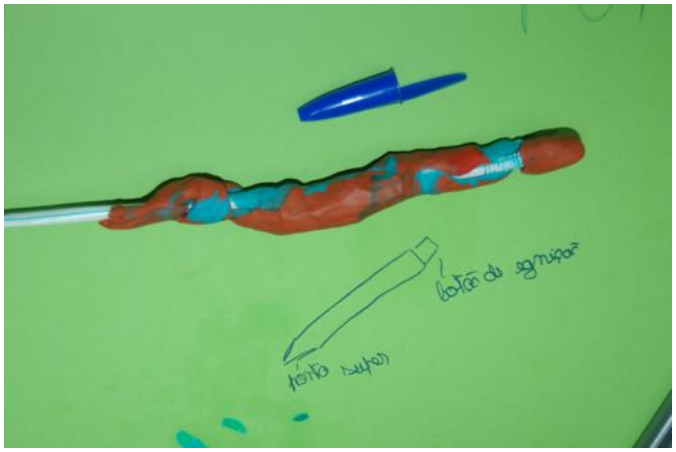
(g) The ‘Expert’ pen features a spiral microphone and writes by itself in many languages.



(h) This pen focused on its customisable design.

(i) For 5 Euro this pen will do your homework for you.

(j) The ‘Bolonix’ pen can complete your homework and exams, in any language for 2 Euro.



(k) This pen uses colour to make an eye catching design.

questions. Children are liable to include almost 'magical' futuristic elements in their designs. However, they were able to create designs that were also very grounded and present potentially interesting functionality - such as a timer function, or the incorporation of a microphone for dictation.

Limitations and Future Work

This ACE Creativity Lab has shown that design workshops with children can be valuable to brainstorm ideas around (handwriting) technology in the context of learning. While our workshop was limited to a specific age and cultural background of children, we would like to run similar creativity sessions with groups of children in the future, considering different age groups, cultural backgrounds, and exposure to technology which will allow for interesting comparisons.

The children in our workshop were able to build viable prototypes using plasticine and other available craft materials. However, incorporating more varied materials may result in a wider range of valuable prototype designs.

CONCLUSION

In this paper, we documented our *Pen of the Future* Creativity Lab where we asked children to participate in creative prototyping sessions to gain better insights into the opinions and ideas that children have regarding the use of digital technology to improve handwriting skills.

Children enjoyed participating in the creative workshop and the large variety of designs reflects interesting and novel features they would like to see embedded in future pen technology. The findings from the presented prototypes provide some insights into features that may be useful in the design of future digital writing tools aimed at children or for educational environments. Repeating the workshop in different contexts and with children of different age groups and cultural backgrounds may open up the discussion up for more detailed findings and comparisons.

ACKNOWLEDGMENTS

We thank all those involved in the organisation of the Creativity Lab, in particular committee members Cristina Sylla, Christiane Moser and Yoram Chisik. We would also like to thank all the others who helped it run smoothly, the facilitators Luis Ferreira and Teresa Paulino, and Paula Alexandra Silva for her help with the translation. We would also like to thank the school and the children involved in our study as participants for their time, enthusiasm and creativity. Last but not least we thank our colleagues of the SACHI group, particularly Michael Mauderer, for their invaluable support and feedback on this work. This work is funded by EPSRC and SICSA.

REFERENCES

1. Arif, A. S., and Sylla, C. A comparative evaluation of touch and pen gestures for adult and child users. In *Proc. of IDC* (2013), 392–395.
2. Bara, F., and Gentaz, E. Haptics in teaching handwriting: The role of perceptual and visuo-motor skills. *Human movement science 30*, 4 (2011), 745–759.
3. Bavelier, D., Green, C. S., and Dye, M. W. Children, wired: for better and for worse. *Neuron 67*, 5 (2010), 692–701.
4. Bonnard, Q., Jermann, P., and Legge, A. Tangible paper interfaces: Interpreting pupils' manipulations. In *Proc. of ITS* (2012), 133–142.
5. Colombo, L., Landoni, M., and Rubegni, E. Design guidelines for more engaging electronic books: insights from a cooperative inquiry study. In *Proc. of IDC* (2014), 281–284.
6. Cornhill, H., and Case-Smith, J. Factors that Relate to Good and Poor Handwriting. *The American Journal of Occupational Therapy : 50*, 9 (1996), 732–9.
7. Donker, A., and Reitsma, P. Usability testing with young children. In *Proc. of IDC* (2004), 43–48.
8. Druin, A. The role of children in the design of new technology. *Behaviour and information technology 21*, 1 (2002), 1–25.
9. Falk, T. H., Tam, C., Schellnus, H., and Chau, T. On the Development of a Computer-based Handwriting Assessment Tool to objectively quantify Handwriting Proficiency in Children. *Computer Methods and Programs in Biomedicine 104*, 3 (2011), e102–11.
10. Guha, M. L., Druin, A., Chipman, G., Fails, J. A., Simms, S., and Farber, A. Working with young children as technology design partners. *Communications of the ACM 48*, 1 (2005), 39–42.
11. Large, A., Nesset, V., Beheshti, J., and Bowler, L. Bonded design: A novel approach to intergenerational information technology design. *Library & Information Science Research 28*, 1 (2006), 64–82.
12. Lindberg, S. Participatory design workshops with children with cancer: Lessons learned. In *Proc. of IDC* (2013), 332–335.
13. Mann, A.-M., Hinrichs, U., and Quigley, A. Digital pen technologys suitability to support handwriting learning. In *WIPTTE* (2014).
14. Oviatt, S., Arthur, A., and Cohen, J. Quiet interfaces that help students think. In *Proc. of UIST* (2006), 191–200.
15. Palluel-Germain, R. A visuo-haptic device telemaque increases kindergarten children's handwriting acquisition. In *Proc. of EuroHaptics* (2007), 72–77.
16. Posch, I., and Fitzpatrick, G. First steps in the fablab: experiences engaging children. In *Proc. of OzCHI*, ACM (2012), 497–500.
17. Read, J., and Fine, K. Using survey methods for design and evaluation in child computer interaction. In *Workshop on Child Computer Interaction: Methodological Research at Interact* (2005).
18. Read, J., and Horton, M. Demonstrating cobweb–an innovative writing environment for children. In *World Conference on Educational Multimedia, Hypermedia and Telecommunications*, vol. 2004 (2004), 1908–1910.

19. Read, J., MacFarlane, S., and Casey, C. Measuring the usability of text input methods for children. In *People and Computers XV Interaction without Frontiers*. Springer, 2001, 559–572.

20. Read, J. C. Children using digital ink for writing. In *Workshop on Pen-Based Learning Technologies*, IEEE (2007), 1–5.

21. Riekhoff, J., and Markopoulos, P. Sampling young children's experiences with cultural probes. In *Proc.of IDC* (2008), 145–148.

22. Rosenblum, S., Weiss, P., and Parush, S. Product and process evaluation of handwriting difficulties. *Educational Psychology Review 15*, 1 (2003), 41–81.

23. Siek, K. A., LaMarche, J. S., and Maitland, J. Bridging the information gap: collaborative technology design with low-income at-risk families to engender healthy behaviors. In *Proc. of OzCHI* (2009), 89–96.

24. Valderrama Bahamóndez, E. D. C., Kubitza, T., Henze, N., and Schmidt, A. Analysis of children's handwriting on touchscreen phones. *Proc. of MobileHCI* (2013), 171.

25. Wellner, P. Interacting with paper on the digitaldesk. *Communications of the ACM 36*, 7 (1993), 87–96.

26. Wyeth, P., Diercke, C., and Viller, S. Design for inspiration: Children, personal connections and educational technology. In *Proc. of OzCHI* (2006), 365–368.

27. Yip, J., Clegg, T., Bonsignore, E., Gelderblom, H., Rhodes, E., and Druin, A. Brownies or bags-of-stuff?: domain expertise in cooperative inquiry with children. In *Proc. of IDC* (2013), 201–210.