Tablet PCs – An Assistive Technology for Students with Reading Difficulties?

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***Abstract*—This paper presents the results of a descriptive case study concerning adoption of iPad or other tablets as assistive technology. Two pilot studies concerning the adoption and use of the iPad for active reading in a teaching/learning situation have recently been conducted at elementary school level and at university level. In the course of both studies, students with reading difficulties were encountered. For each group of students, a key case has been chosen. The paper presents our findings regarding adjustments that needed to be made for these students and initial research on iPad usability for students with special education needs. By describing two instances, one involving a university student and the other two elementary school children, we hope to bring attention to application of ICT for students with reading difficulties. Students with this kind of impairment are often neglected in comparison to students with visual impairments or other disabilities. In one case, the iPad has been successfully integrated into students' life as an assistive technology. The cases may be both instructive and inspirational for educational situations involving students with similar disabilities as adjustments and applications used to help students do not involve any large investments in software or devices.**

Keywords-assistive technology; iPad; reading difficulties; tablet PC; technology adoption

I. INTRODUCTION

Two pilot studies involving the use of iPads for active reading in a teaching/learning situation have recently been conducted [1], [2] and [3]. One of the studies has involved University students and the other, 4th grade children in elementary school. The goal of the studies was to explore the potential of mobile and wireless technologies (the iPad was used in both cases) to change classroom information ecologies and enable anytime anyplace learning situations. The concept of information ecology was introduced by Nardi and O'Day in [4] as "*a system of people, practices, values, and technologies in a particular local environment*" and it focuses on five defining characteristics 1) it is a *system* 2) the system contains *diversity* of people and tools 3) there is a change or *co-evolution* happening over time and through use of technology 4) *keystone species* are part of the ecology (their presence is critical for the system's survival) and 5) *local habitation* (the habitation of technology is its location within a network of relationships). Nardi argues: "*Human expertise, judgment and creativity can be supported, but not replaced by computer-based tools."* One should contemplate the technology with both the head and the heart and not fall prey to either technophilia or technophobia. The approach based on classroom information ecology was taken in all the studies we conducted with iPads.

In [5], Turkle states the following regarding computer technology: "*Most considerations of the computer concentrate on the "instrumental computer", on what work the computer will do. But my focus here is on something different, on the "subjective computer*". *This is the machine as it enters into social life and psychological development, the computer as it affects the way we think, especially the way we think about ourselves. We saw both the view of "instrumental tablet" and "subjective tablet"."* The instrumental side answering questions around how the iPad may be best used in the classroom and outside of the classroom for the purposes of learning. The subjective side addressing the plethora of factors such as personal relationship with iPad, social changes it induces, taking a larger freedom in designing the curriculum (empowerment), avoiding stigmatism in cases of children with special needs, self-image, changes in a way of thinking and interacting with technology etc.

The personal relationship to the device opens up for the new uses of the iPad in the classroom setting, such as assistive technology (AT) for children with special needs (see, for example, [6]).

The adoption of tablet PC as an assistive technology became the subject of our case study that was conducted from September 2010 until September 2011.

In this paper, we will focus on two cases that we have worked with, involving students with reading difficulties. The first one is a University student whom we will call Mary in this report. Mary is diagnosed with dyslexia. She was highly motivated on her own to work with this new possibility iPad offered.

Our second case presents a much more sensitive situation, involving two elementary school children, whom we will call Iris and Josh in describing their case. Iris and a Josh are both aged nine. These children do not have any kind of diagnosis. Neither the teacher nor parents are trying to have the children diagnosed. This approach may have some advantages such as protecting the children from stigmatization, but it also has problems. The main issue is children's low self-esteem [7, 8]. Iris, in particular, has a twin sister at school, with no impairments. On the contrary,

 ISBN: 978-1-61208-177-9

the sister excels in academic achievements. Iris is aware that she does not perform as well as her sister. Josh may or may not be aware that he has a problem at all. So this case is extremely interesting for bringing to light issues related to awareness of the existence of the problem and its acknowledgment that can have effects on the policy making for schools regarding AT, rather than silencing it until the students are older.

While the causes of dyslexia may be complex to understand, it often manifests as a learning disorder marked by impairment of the ability to recognize and comprehend written words. A significant proportion of students seeking help from the Accessibility Services at the University of Oslo are diagnosed with dyslexia. About 46% of those [9,10] are first diagnosed after they start their higher education. This fact is in stark contrast to other kinds of disabilities such as visual impairment, hearing loss or physical impairments, which are usually diagnosed much earlier. This is important both for how fast and how much help these students get in order to minimize the impact of their impairment on learning [11]. A further complication with offering help to dyslexic students is that they often require individual adjustments.

In parallel with technological developments, from hardware to Internet and Communication Technologies (ICT), systems for dyslectic and visually impaired users have been developed. The effects of these systems have been reported in a number of different studies [12]. For instance, it has been found that different voices reading the text have an impact on the user's text comprehension [13].

School and university libraries have traditionally offered help for their users with dyslexia or visual impairments. Libraries would often have expensive equipment such as a special enlargement screen and computers using "text to speech" software. The reasons the libraries have all this special equipment is the prohibitive cost of the equipment paired with "access for all" philosophy. An additional benefit for users was help with mastering of this rather complex equipment generously provided by library personnel.

With the arrival of the e-book readers, and later tablet PCs, this scene is changing for dyslexic students. What they had to go to the library for before, they could now have with them, anywhere, anytime. A new world of possibilities has opened up for the dyslectic community, although tablets may be used as assistive technology (AT) for other kinds of impairments as well [14].

In the first case, Mary cooperated with us in trying different approaches, meandering between problems and solutions until we found what works for her. After more than a year of following Mary's iPad use, we can report that this technology has made a significant difference in her academic performance and she became somewhat of a virtuoso in handling her iPad. In [15] the author states: *By using the very digital media that is helping drive this information society, computing technologies may be a viable means of providing reading support and accommodation. For such technologies to be successful, though, they must be adopted into regular use. Unfortunately, studies have shown that 35–50% of all assistive devices are abandoned after purchase.* Mary has made a margin of those who keep on using their AT.

In the second case, such an open approach was not possible. Instead, an experiment involving the two children with reading difficulties and a control group was carried out. The experiment helped us showcase the potential the iPad (or another tablet) may have as an AT for children with reading difficulties.

Both cases suggest strongly that at least some portion of dyslexic students could be helped by similar means. In [15] it is pointed out that many factors (socio-cultural, technical, economic, environmental etc) influence adult adoption of assistive technology. We find that all those same factors influence the children. Invisible nature of reading disorder and even stronger impulses not to disclose it are of huge importance with children. The statistics valid for adult population (5-15%) are probably the same within the young population, except that these are not available, in part due to the invisibility issue. Therefore it is of large importance to bring awareness to this situation. Some of the methods developed for adults such as Value Sensitive Design proposed in [14] may be of use with children as well. The mobile AT adds additional value in that it does not draw attention to the person using it (as opposed to sitting in a special room in the library, in front of a huge screen). Someone "reading" the text by listening to it from the iPad looks quite "normal", but the impact of this kind of AT may be quite huge on children's education, social life and self-esteem among other things.

The technology adoption issues are difficult in the best of circumstances with so many factors influencing the success or failure. Assistive technologies are even more difficult. However, from 2020, universal accessibility will be enforced by law in Norway, and thus it is timely to investigate how this can be done in the classroom.

From the design perspective, solutions found for groups with special needs often find their way to the mainstream. In this case, tablets may become an example of a device designed for the mainstream, but having potential to be accepted and adopted by groups with special needs.

II. THE APPROACH TO THE PROBLEM

The research conducted around the two pilot studies [1,2,3] has organically led to discovery of students with disabilities. We, at the beginning of the pilot studies, did not have any intention to study the use of iPad by students with dyslexia, but we thought that seeing what Mary does with the tablet will be very interesting. We were going to interview her periodically and record what happens. However after the very first interview with Mary, we realized that we would need to take an active role in making adjustments for her, as well as observing her in the class, having interviews both with other stakeholders, such as software producers or anyone else who could help her. We needed to think of what kinds of software, applications as well as potentially other devices would work for her. We also quickly found out that it is fascinating to learn about learning practices of dyslexic students. And so it also unfolded into looking at policies including privacy, role of environment, social and cultural positioning of the student, and the role of teachers. This paper will cover only the

 ISBN: 978-1-61208-177-9

grounds of how the technology became part of Mary's everyday life, and how working with her inspired us to look at the reading difficulties in younger children. We find the problem of adoption of technology in the case of young children even more challenging, due to the fact that they themselves are often not aware that they have difficulties with reading and learning that can be helped.

The nature of the problem that we were looking at was such that only a few subjects were available for the study. Thus, naturally, a case study (see for example [16]) became a method of choice. We use a descriptive case study, an in-depth study of a specific instance of assistive technology adoption, with explanatory purpose, placing the spotlight on what might become important to look at more extensively in the future research. Our techniques have included direct observations in class, interviews with Mary, and interviews with elementary school teacher as well as Iris's family.

III. MARY'S CASE

Mary was appointed by the University of Oslo Accessibility Services to participate in a larger project, involving introduction of the iPad into a geology course [3]. In practice, this meant that Mary received an iPad to use. She did not get any special support with it, except for having Dropbox, iAnnotate, and a 25$ gift card as part of the iPad deal.

Some major problems that she encountered while attempting to use the iPad to her advantage, were disclosed during our first interview with her. This was the story in a nutshell: since Mary is dyslexic, the Norwegian Library for the Impaired (NLB) was charged with the task of finding, if available on the market, curriculum for her in speech synthesis. Usually, the curriculum is delivered in the Daisy file format, which contains both speech and text. Using special software, Mary should be able to hear the text and watch it being highlighted at the same rate as the speech is progressing. However, the Daisy file reader was made for the Windows platform and Mary is a Mac user. The NLB could not locate the software for Mac or iPad. On her own initiative and without help, Mary tested several free applications from the Appstore that can read Daisy files on the iPad. But she ran into problems again. The Apps would crash all the time. She thought the problem was caused by lower quality of the free software, and thus, she bought a $30 full price version of the Daisy reader. There was no improvement. The program kept crashing. With some evident frustration, she shared: *"So I tried some different software that worked a little, but it froze often, both audio and text, and sometimes the iPad went completely dead!"*

There were other technical problems contributing to this negative overall experience. An example is that the student housing where she lives, has no Wi-Fi connection. *"If I had an Internet connection I would have used it (the iPad) more actively"*. In summary, Mary was not really able to use the iPad in the ways she wished and needed to do.

We made a joint agreement to give it another try during the following semester (Spring 2011). One of the authors started investigating the problems with the Daisy files. The application Mary bought to play Daisy files with on the iPad was Voice of Daisy (VOD). After testing it on another iPad with no improvement, a request for information on the files and plea for help was sent by email to NLB. Although the library showed huge interest in our approach, the only information we got was how the CDs with Daisy files were produced in the house. A second effort was then made involving contact with the Japanese developer of the VOD application. After several emails, they resolved the problem. The reason for crashing of the App was the poor quality and the erroneous offset of the files she received from the NLB.

As part of the agreement between the student and us a supplementary intensive support period was given to her, teaching her how to use the iAnnotate and other iPad applications. Mary also agreed on monthly interviews with the authors, in order to make sure that the progression of the use of the iPad was not interrupted by yet another technical problem.

It is very interesting to note that we have asked if we could observe her working with the iPad in her courses. Mary at once agreed to be observed at the lectures, with many students attending. However, she definitely did not want to have anyone observing her at small work group meetings that are part of the course set up: *"If I let you do that, then I for sure will not make any friends in this class."* Mary spoke directly about the issues of stigmatization in relation to her need for assistive technology.

During the next few meetings in the spring semester she reported increased use of the iPad for studying. And then, one day it all fell into place. With some help, she had developed her own way of working with the iPad, turning it into a proper AT tool. She was able to use it anytime, anywhere. And most importantly, she really enjoyed it!

Mary was using different applications for different needs. Voice of Daisy was used for the part of the curriculum involving books. For articles she used two applications simultaneously. The first one was Speak-It with the possibility to cut and paste part of the text and hear it. The second one was iAnnotate where she could mark the text, annotate it and enlarge it while simultaneously listening to it. She was very pleased with the fact that she could choose part of the text she wanted to hear, and was not forced to listen to the whole text. She found her "own" special ways to use the color and the strikethrough (see Figure 1).

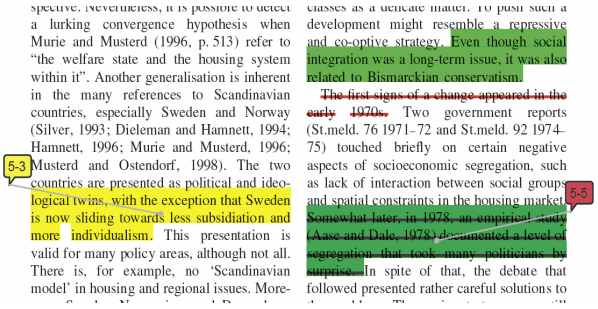

Figure 1. Example of how Mary worked with text while listening to it.

The color was used to group similar topics, while the strikethrough was used to remove uninteresting parts of the text. The tactile interface made quick selection of the text

possible. Using a normal laptop and mouse interaction would have taken much longer. Mary's interaction with the iPad also became beautiful to watch; her movements are quick, certain, effective, lightly dancing around the touch surface (see Figure 2).

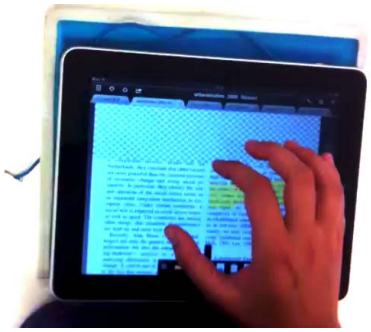

Figure 2. Mary is engaging with the text before it even loads fully.

Using VOD on the iPad was also easier than on the PC. She explains: *"Zooming in and out gives me a better view. For example, I can always quickly find out where I am in the text."*

In the classroom, she had the possibility of taking and grouping all her notes on the iPad, using the default software such as Notes shown in Figure 3.

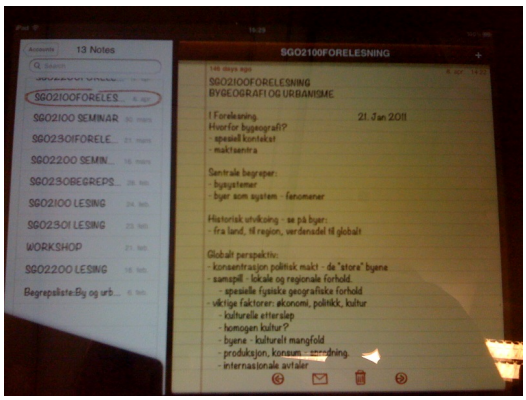

Figure 3. Taking notes in class on the iPad

The aftermath of these joint efforts to make the iPad into an AT shows that Mary's interest in her field has increased; her confidence in being able to finish her studies has increased and her overall attitude towards AT has improved.

IV. IRIS'S AND JOSH'S CASE

In the beginning, the children with reading difficulties were indistinguishable from their peers. Together, they made up a class of 26 students in a rural Norwegian school. Six iPads were given to the class, five for students and one for the teacher. Classroom got wireless connectivity in conjunction with the pilot study, thus enabling wider use of the Internet. Digitalized curriculum is not yet common in elementary schools. In spite of this, access to digitalized curriculum was obtained from the academic publisher (free of charge) for Religion Studies, Mathematics and Science. English is relevant both as the subject at school and as the language of applications. The students have some knowledge of the language, but many are far from fluent. The traditional way of teaching English was supplemented from the start of the study with stories and Apps (such as Alice in Wonderland or balloons) that could help students to improve their English through play. One day per week was set as an observation day.

All of the children were rather excited about having the iPads in the classroom. They could also bring them home (according to the schedule they made).

From the very start, we observed that many pupils liked enlarging text, sometimes quite a bit (see Figure 4), while reading.

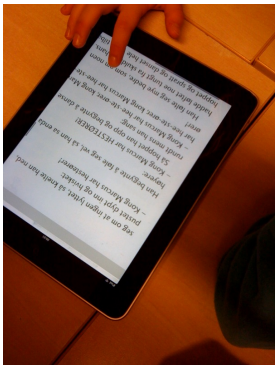

Figure 4. Iris is enlarging text while reading

It is worthwhile mentioning a study [17], done on Kindle, but with similar possibilities to enlarge letters. The authors report: *"The Kindle provides a choice of six different font sizes. During this study, Amy generally kept her font at a larger size than Winnie. In an interview, she explained that it helped her "read faster when the text was large." The varying text size did create some challenges on days when the girls decided to partner read, as the visual layout of their Kindle "pages" differed. The girls quickly learned to synchronize their settings when reading together."*

The preference for larger text and ease in reading with large letters is related to dyslexia [18]. If a child enlarges the text to an unusual size, it signals that the child may have reading difficulties. Both Iris and Josh do prefer to read on the iPad to reading from paper, mainly because of the ability to enlarge the text.

When iPads were collected for the first time in order to see what kind of content the children have placed on their them, one iPad differed from others significantly (see Figure 5). Josh has organized all the content into thematic groups, being displayed quite neatly on the iPad. That was strange, but even stranger was the fact that one of those groups had to do with languages and translating from one language to another using speech.

The organization of content soon became a class standard, but no other students ever installed apps for learning languages or translating from one language to another. These actions made Josh visible to us.

 ISBN: 978-1-61208-177-9

Figure 5. Josh's iPad, compared to another one from the class. Note: the third item in the first column is a category marked as snakk (trans. speak), containing language speech based applications

In the course of the pilot study [1], Iris and the rest of her family were interviewed twice. During the first interview, the parents pointed out that the girls are "much more" interested in homework, especially the one of them that has some problems with reading. This is how we got interested in Iris.

In a later interview with the teacher, it was confirmed that both children have difficulties reading. However, the teacher told us: *"This is very, very confidential."*

The teacher had some specific wishes regarding the use of the iPad in class as assistive technology for children with special needs. She said: *"Groups who need special education can be helped by the school. Having some iPads could be like "a carrot on the stick" for students who cannot be helped so easily and who are struggling a lot"*. (trans. Culén). The statement, positive as it is, also had a note of resignation in the face of the complexity of the problems comprising the child's self-esteem, self-perception, perception by others (often involving stigmatization), parents' involvement etc. On top of these challenges the school would also face organizational challenges around supporting the adoption for everyday use coupled with adaption to the needs of an individual student.

The teachers comment about confidentiality has made direct inquiry with children impossible, as well as use of the same approach as we had with Mary. We were limited to direct observations and questions around why do students like to use the iPad.

Figure 6. The children participating in an experiment comparing the understanding and retention after reading from paper and ipad using SpeakText program.

In order to be able to grasp what kind of difference in comprehension the iPad (through text-to-speech App SpeakText, see Figure 6) could enable for these two children we designed a simple experiment. The experiment engaged five children: the two with reading difficulties, and 3 without difficulties, including Iris's twin sister. The purpose of the experiment was to give and indication of what could be done with the use of iPad, and not to provide any statistically significant results. The real purpose of the experiment was not presented to the students for confidentiality reasons. Rather, the experiment was presented as testing of the effectiveness of reading on the iPad.

A. Experiment design

Our null hypothesis was that there is no difference in understanding the text for children with and without reading difficulties when they read from paper and when they select the text on iPad and heard it read to them. It involves two independent variables each having two conditions (children with and without reading difficulties and reading from paper or iPad's app SpeakText).

The dependent variable (understanding of the text) was measured by how the children answered 8 simple questions after the reading (or hearing the text). Four of the questions were retention (memory) based and the other four based on understanding causes and effects in the story.

Due to the small number of children with reading difficulties that we could recruit, the within the group design was an obvious choice. Thus each student repeated the reading session, followed by the answering session, twice – once with paper and once with the iPad, where which was to be done first was determined at random (see Figure 6).

The reading was done from two distinct passages from the same text, approximately equal in length (374 words vs. 380 words), from a children's book. The iPad app SpeakText, with voice over text and highlighting while the text is being read, needed 3 min. and 18 seconds to read the 380 word paragraph. The children's reading from the paper based on 374 words was timed for all five children. The clock was stopped when the child indicated that they have finished reading the paragraph. In one case, there is a slight imprecision due to the fact that we did not stop the watch precisely enough when the child indicated that she finished the reading. The result is given as an approximate time in Table 1.

The answer session was not timed, but the children knew what to expect the second time around and they were somewhat faster on the second set of questions than on the first, indicating that some learning effect has taken place.

B. Results

Table 1 summarizes the results obtained from children without reading difficulties. Table 2 summarizes the results from those with reading difficulties. Each field in the table gives the number of questions that were answered correctly by the child. As mentioned above, in conjunction with paper reading, the reading time was recorded (the iPad time was always 3 min. and 18 seconds). After the reading was over, the questions were handed in and the students could no longer view the text they just read (or heard).

 ISBN: 978-1-61208-177-9

TABLE I. SUMMARY FOR CHILDREN WITHOUT READING DIFFICULTIS

Under-standing	Child 1	Child 2	Child 3
iPad			
Memory	4	4	4
Comprehension	4	2	3
Paper	Time 1:54	Time 2:27	Approx. 2:30
Memory	3	3	4
Comprehension	4	2	3

TABLE II. SUMMARY FOR CHILDREN WITH READING DIFFICULTIES

Understanding	Child 1	Child 2
iPad		
Memory	3	4
Comprehension	2	4
Paper	Time 15:29	Time 6:27
Memory	2	1
Comprehension	0	0

Note that neither of the children with reading difficulties has answered any comprehension questions when reading from the paper. Retention questions did not fare much better. Although not perfect for both children, the results after the iPad use were improved. It is also interesting to note that for the children without reading difficulties, the iPad use shows slightly better results.

These results are, of course only indicative due to a very small sample size.

Post experiment, we collected impressions from the children around the experience of reading from the iPad. The children remarked that they liked zooming on the text as well. Iris in particular mentioned twice that zooming helps her. It would have been perhaps interesting to repeat the experiment with both readings from the iPad, one of them with possibility of enlarging the text and the other one with SpeakText App.

V. CONCLUSION

In the process of working with the two cases, we believe to have seen how tablet PC can bring forward some new possibilities as AT in this sensitive and complex field.

In spite of the small sample size, the case of elementary school children, at the very least, indicates the need for more research related to AT. Our hope is that larger studies will be conducted at elementary schools worldwide, inspired by this, and similar small studies. We view the outcome of this study to also be a contribution to the body of evidence that mobile technology may be in some cases effectively used as AT.

The introduction of the iPad in the elementary class has, in general, been a success. In particular, it offers clear support to some children with reading difficulties. Even in the situation where the impairment itself is confidential and kept in silence. While it is still true that each child/student with dyslexia or with reading difficulties needs individual assessment as to what works and what does not work, there is a number of possibilities that were very simple to try with iPads (things like different apps for text to speech, changing synthetic voices in order to find the one that works the best, enlargements, color annotations etc).

A very important point in favor of mobile assistive technologies is that it minimizes stigmatization for the ones using it. For example, for Mary, she could sit in the classroom with her headset on and listen both to the text and to the lecturer, without anyone thinking that this is strange or even noticing it. Thus the stigmatization problem is minimized at the same time allowing the user to attain more self-confidence in academic arena.

In Iris's and Josh's case, the results of the experiment we conducted have convinced the teacher and given her the will and the encouragement she needed in order to support this kind of iPad use in her class. Silently and inconspicuously for the time being.

Finally, future work as we see it lies in conducting series of smaller studies showcasing how different impairments may be helped, followed by larger studies validating the smaller ones and convincing the school leadership and the policymakers as well.

ACKNOWLEDGMENT

The authors are grateful to Akademika, the University bookstore and publishing house for providing the iPads for the study, Gyldendahl academic publishing house for providing digitalized text the children could use and the University Library for the support.

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