An Evaluation of Digital Pen and Paper Technology in Classroom Administration

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Abstract—**This paper contains the results of the MTT project concerning the viability of digital pen and paper technology (DPPT) for administration in a K-12 classroom environment. We evaluated filled out forms and made interviews and user tests with teachers to show the advantages and disadvantages of DPPT compared to regular methods for attendance tracking and grading. Additionally, the paper addresses the problems that arise with DPPT in a classroom environment and includes suggestions how to deal with those.**

Index Terms—**attendance tracking, classroom administration, digital pen, grading.**

I. INTRODUCTION

Classroom administration is becoming more and more of an issue for K-12 teachers. A growing requirement to document the teaching processes and student developments leads to teachers using more and more time for administrative tasks and them having less time to focus on individual students. As described in [1], School avoidance is often detected too late and it is hard for teachers to give individual feedback to students or their parents if they teach large classes and have to spend more and more time on documentation tasks.

The standard German system of tracking attendance information with a class book is cumbersome and highly insecure as no backup is created and data have to be tallied up by hand at the end of a semester, Alarming trends are often only realized at that point as individual teachers rarely communicate their issues with students to one another or the principal. See [2][1] for a detailed explanation of these problems.

The one year long master project Mobile Tools for Teachers (MTT) at the University of Bremen implemented and evaluated a prototypical system that uses digital pen and paper technology (DPPT) for classroom administration. DPPT uses a special pen and paper with a special pattern printed on it to capture handwritten information. The system allows teachers to track attendance and grading information on paper while digitalizing said information at the same time. This way a copy of all information is created as well as a central point where authorized persons can view the data. The assumed advantages of the system were twofold: On the one hand the system was designed to save time spent on classroom administration by eliminating such tasks as sifting through handwritten attendance information at the end of a semester. On the other hand the project aimed at giving various parties better access to information that is collected in schools, allowing for example for early detection of school avoidance and faster finding of final grades. This paper deals with the evaluation of how well these goals were achieved and how suited DPPT in this setup is for classroom environments in general.

We assumed that a system using pen and paper would require next to no training on the side of the users and would be much more likely to be accepted by users who are not very familiar with computer technology. This assumption was based on informal interviews done with a few teachers at the start of the project as well as findings other scientists had with different technologies in a teaching environment. Jocelyn Wishart, Angela McFarlane and Andy Ramsden from the University of Bristol, UK for example, studied the usage of personal digital assistants (PDAs) among science teachers in training. They found out that the "use of their PDAs dropped during the main 12 week block of teaching practice when they are placed in schools full-time. Some trainees reported that under pressure of time and workload they reverted to use of paper and pen to organise themselves and plan their teaching" [3].

Additionally it appears, that graphical interfaces can distract from the actual task at hand. Sharon Oviatt, Alex Arthur, and Julia Cohen compared math students' use of different technologies for solving math problems. They found that students' "ability to think at a more abstract, strategic, and self-reflective level about the process of solving math problems declined significantly when using the graphical tablet interface" [4].

If computer based systems such as PDAs are too complicated to use in stressful situations, it seems natural to use a tool that allows teachers to stick to pen and paper while still providing the functionalities of a digital system. Various models on the acceptance of technology, such as the Technology Acceptance Model TAM [5] and the Structural Model of Educational Technology Acceptance Model Integrated with Educational Ideologies [6] put a large emphasis on the perceived ease of use of a technology, thereby predicting a high acceptance for the digital pen technology. The MTT system was implemented with the cooperation of and tested at the International School of Bremen (ISB), a "private, co-educational, college-preparatory, English-speaking

Manuscript received June 02, 2008. This work was supported by the ifib institute at the University of Bremen and the bendit GmbH.

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Stundenberichte der _____ Unterrichtswoche

	Std.	Fach	Durchgenommen	Aufgabe	a) Versäumnisse b) Verspätungen c) Bemerkungen	Signum
Montag	1.					
	2.					
	3.					
	4.					
	5.					
	6.					
	7.					

Fig. 1 - Excerpt from a German class book as sold by the Seibert Verlag (http://www.seibert-verlag.de).

school"[7]. Classes in the ISB are generally smaller than those in public German schools. We originally intended to work with the German Wilhelm-Olbers-School [1] as well, however cooperation was slow and had to be terminated after a few meetings. Our time limits in combination with school response times did not allow us to switch to another school.

A. Attendance tracking and grading in German schools

Whereas the MTT system was eventually tailored to the needs of the teachers at the ISB, its core elements were designed with the standard German system in mind. We used a combination of our own experiences in German schools and the investigation at the Wilhelm-Olbers-School in Bremen as a basis for this. German schools usually use class books or course books to track attendance data and general lesson information [8]. Normally one book is used for each class and for each semester, some schools split students into course books instead, making one book per course and semester necessary. These books contain two types of information – general information about the class and information about individual lessons.

The general part of such a book consists mostly of a list of all students who are in that class or course, a general timetable, and a list of exams which were written or will be written.

The daily part consists of detailed information about the content covered that day, as well as students' attendance. Fig. 1 shows an example of such a sheet. The main structural element of each page is the day's timetable. In this timetable there are columns for subject, content covered in that lesson, attendance and the teacher's signature.

Some of the information entered on such a sheet has to be entered each day, some is optional. Class books are often handled by a designated student in each class that carries them around to the different teachers. Course books on the other hand often stay with the teacher.

Grade tracking is usually not standardized within a school. It is up to each individual teacher how they grade their students and how they keep track of these grades. The calculation of a final grade from intermediate grades is also up to the teachers, leaving them to find their own system of weighting different grading types. Commonly used methods include small grading books with rows for each student and spreadsheet software.

B. Special case: the International School of Bremen

The system at the ISB is different to what German schools use, much more akin to the system in the USA. Teachers have fixed rooms and the students always have to change the room for the next class, in German schools there most of the lessons are given in the class's classroom [8]. Attendance is only checked once per day at the ISB, from 8 am to 8:10 am. The students have to meet with their class teacher in his or her room at that time so that attendance can be taken.

When we started working with the ISB in 2007, each teacher had a list of his students on a sheet of paper. The teacher filled out this list in the morning and sent a student downstairs to the secretary who checked if a missing student was excused or not and took appropriate action. Normally this process took the whole 10 minutes allocated to it, from the beginning of attendance tracking until the student returned.

During our collaboration with the ISB, they switched to the computer based management information system Facility by the Serco Group plc[2]. Due to the existing infrastructure at the school - each teacher has a PC in his or her room - it is possible for them to track attendance using a computer. The process now is as follows:

The teacher has to log into the Facility system with his or her personal login and password. Then he or she selects the class list, which has two columns. The first for the name of the students (already inserted) and the second is for a character from the legend (such as E for excused or L for late). The legend consists of nearly 20 possible characters but only 3 to 4 were used regularly. After filling out this list, the teachers save it and the secretaries have to check all lists on an overview page on their own computer.

Ideally the whole process takes about 2.5 minutes, but it can be prolonged by the class (number of students, discussions, questions, late comers, etc), by the computer (speed) and by the teacher himself.

Grading at the ISB is done similar to German schools – in a non-standardized way. A seemingly cosmetic difference is that the ISB uses grades from 7 to 1, where 7 is the best grade.

C. Digital pen and paper technology

The digital pen and paper technology referred to in this document was developed by the Lund, Sweden based Anoto Group AB[3]. A ball point pen is combined with a digital camera and a storage and processing unit to form the digital pen. Writing on paper that was pre-printed with a special pattern of small black dots allows the camera to obtain position information. This pattern is usually found on forms that have been designed for the use with the digital pen, consisting of text fields (free and dictionary based), check boxes and special command boxes called pidgets. All data collected with the pen are then mapped to an electronic representation of the form layout, providing meaningful information.

This DPPT implementation makes a difference between so-called unique pattern and copied pattern. If a page is printed with unique pattern that means that the pen can identify the exact page you are writing on through the

[1] http://www.szdrebberstrasse.de

[2] http://www.serco.com

[3] http://www.anoto.com

alignment of the dots. The less expensive approach is the copied pattern one, which uses the same pattern on each sheet of the same type. This saves licensing and printing costs but makes it impossible to uniquely identify the sheet that was written on, usually solved through user interaction (i.e. filling out a date or ID field).

The MTT project used a server provided by the Bremen, Germany based bendit GmbH[4] for this mapping and the subsequent character recognition. The bendit software combines stroke information from the pen with a dictionary approach to obtain better recognition rates.

D. The MTT system

The MTT project implemented a prototype of a system that uses digital pens developed by Anoto to track attendance and grading information written on special sheets of paper, the MTTForms. These pens transfer their data via USB to a personal computer that then sends them via the internet to a server for processing. After intelligent character recognition[5] is performed, all data are stored in a database and can subsequently be accessed through a web interface called MTTWeb. The web system allows for different views on the collected information, such as graphs showing the development of students over time.

The attendance tracking process was modeled closely on the principle of the German class book, using forms that should be intuitive to use for anyone that has used a class book before. Grades are tracked on special grading sheets which are pre-filled with student names and allow teachers to quickly write down grades for different types of examinations. A detailed description of the MTT system can be found in [2].

E. Previous studies on the digital pen and paper technology

The DPPT has been used in a number of pilot projects previously. Scientists at the University Hospitals of Geneva, Switzerland tested the technology in a clinical environment [9]. While they collected positive user feedback in general, they identified some issues with both handling of the pen and data accuracy. Users in their study wrote 30% of all data entered outside the predefined boxes, making them invisible to the system. They did not get any results on the quality of intelligent character recognition, but stated that "the quality of data obtained with the digital pen was always less or equal to that obtained with a scanner, when performed without any additional human intervention" [9]. They did not compare the results of the pen to those acquired manually.

Similar results come to us from a group of scientists at various hospitals in Bonn, Germany [10]. They used the pen to capture vital sign data in acute care settings and concluded "that data do need to be verified before they are transferred to the repository" [10]. They also found a high general acceptance of the technology among study participants. An overview of results of studies about DPPT in clinical environments can be found in[11].

II. Methodology

The study described here had the goal to prove or disprove the following assumptions: DPPT as used in the MTT system saves time, DPPT only requires minimal amounts of training and can easily replace previous methods and tools for attendance tracking and grading, and average users will have more problems with the web interface than with the pen

The evaluation of a concept with large scale and long term results such as the MTT project is inherently difficult in a limited time frame. After completing the prototypical system, the project members had three weeks time to test it on actual teachers. Ideally one would have a large group of teachers with different backgrounds use the whole system for at least one semester to see how it performs in an actual use context. In order to still get relevant results we collected attendance and grading data long before the system was actually in place, so that the web interface could show real data for the teachers to use. These data were manually entered into the database, Still the data in the system were not complete due to several issues such as a low form return rate at the start and incorrectly filled out forms, and could therefore not be used to perform the teachers' actual tasks. To circumvent this problem we designed a number of problems that the teachers were asked to solve under supervision. Six of initially eight teachers at the ISB participated in the experiment. These teachers had been working with the MTT forms for a few months and were trained by project members in their use. They also got a brief introduction into the web system before they started the experiment.

A. Practical test & observation

Each teacher was handed a short instruction booklet on how to use the system, a list of five tasks to perform with the digital pen and in MTTWeb, a grading sheet, a class book sheet and got access to the web system. Using the digital pen they had been handed previously, they performed the following two tasks:

1. Imagine you performed a test in one of your classes last week. All students except for [name removed] (10^{th} grade) or [name removed] (9^{th} grade) respectively were present. The absent student was excused. One of the students (choose one) was present but handed in an empty sheet of paper for the test.
    a. Give grades as you see fit.
    b. Synchronize the pen with your computer.
2. You are the first teacher to fill out the class book sheet that day.
    a. Fill out the form for the situation described in task 1.

All participating teachers had been using the digital pens and the MTTForms for several weeks and were therefore expected to have little problems with these two tasks. The following three tasks incorporated the web system which the teachers had only seen once previously in a fifteen minute presentation.

3. [name removed] (9^{th} grade) or [name removed](10^{th} grade) came to you after the test was returned and pointed out that he or she should have gotten a better

[4] http://www.digipen.de

[5] The term intelligent character recognition (ICR) is used here instead of optical character recognition because it relies on stroke information and not pixel information and because it is able to use dictionaries for a better recognition rate. The ICR used by the bendit GmbH is not a learning system, however.

grade. You agree. Log into MTTWeb and change the grade in question.

4. You need to come up with a final grade [name removed] (9th grade) or [name removed] (10th grade) respectively. Use the grading aid function to determine a final grade.
5. You are preparing for a meeting with the parents of [name removed] (9th grade) or [name removed] (10th grade) respectively and want to use MTTWeb to collect information on that student beforehand. Collect the following data by either printing or saving them in a pc document (i.e. using MS Word)
    a. Exam and oral grades of the student in your class throughout the semester
    b. Attendance of the student in your class during the semester
    c. Average grade development of students in your class throughout the semester

These tasks were carried out on each teacher's personal computers in the school. Each teacher was observed by a project member throughout the process using specially created observation sheets, modeled on the qualitative research methods laid out by R. Bogdan and S.J. Taylor [12]. The observation sheet for the first two tasks asked for the time taken to perform the tasks, detailed competence in using the forms and the pens as well as a general overview on how well the individual teachers did. The three tasks concerning the frontend MTTWeb had their own observation sheet, looking again for the time taken, competence and problems using the system and general observation. Both sheets included room for handwritten comments by the observer.

Most parts of the observation sheets where designed to be easily quantifiable and could therefore be entered into and statistically evaluated with spreadsheets. The individual comments were condensed in a text document, clustered and then statistically evaluated.

B. Interviews

Each of the teachers that did the tasks described above was afterwards interviewed to get a more in depth view on how they performed using the system. These interviews were done by six different interviewers and therefore potentially biased. In order to minimize the influence of the interviewers on the results, they were handed detailed interview guidelines. These contained a combination of questions with binary (yes/no) or numerical (seven point scale) answers and open free text questions. The interviews focused on the tasks described above and were designed to answer the questions of this evaluation.

Binary and numerical answers could easily be quantified and used for statistical analysis, the free text answers where condensed in a text document, repeated answers identified and categorized as positive or negative factors for the system.

C. Form analysis

In addition to the direct experiments with the teachers of the ISB, we also collected all the forms they filled out within the project timeframe as well as the data transferred to our web server as soon as the teachers were equipped with the digital pens. A set of guidelines we developed allowed the categorization of mistakes on the forms and problems with the intelligent character recognition. With these tools we could then quantify issues on the form side of the system.

III. Results and Discussion

This chapter answers the questions brought up in the introduction, split up into a general evaluation of a DPPT system in schools (using the ISB as an example) and the specific evaluation of the MTT System.

A. Viability of the digital pen in a classroom environment

One of the main assumptions that lead to the MTT system was that the digital pen is a highly viable tool for the use in a classroom environment. The high mobility and low learning threshold of a system that is based on pen and paper are the major distinctions from implementations that use technology such as the PDA or personal computers.

Five of the six interviewees told us that they could imagine using the digital pen every day and none said that they could not complete the tasks they were given for data entry. Multiple teachers also commented that the digital pen was easy to use and felt good in their hand. Only one found it too bulky and not actually a handy tool.

This high acceptance was not reflected very well in the return of forms, both on paper and through the digital system. Only two of the teachers regularly used the digital pen to add data to the web system throughout the three week testing period. This, however, is at least partially due to the lacking test setup with only eight teachers that had to use our system in parallel to their normal one. It can safely be assumed that the return would be much higher if the system was implemented for a complete school as the only system, therefore not adding additional workload to the teachers' schedule.

Three teachers saw as a problem that pens could not be kept safe in schools and four admitted problems with using the same pen each time. The first problem is a limitation of every mobile technology – the higher the mobility of a piece of hardware the easier it is to steal or lose. Stealing should be less of a problem with the digital pens though, as they currently can only be used with the system they were licensed for. This fact probably won't change unless the technology is made available as stand-alone software. Using the same pen each time to track attendance and grades is more likely to be a problem. Most teachers seem to manage to keep their personal notebooks safe and with them, however, and appropriate training should enable them to do the same with the digital pen. The pen is, as mentioned by one of the teachers, an additional device that needs to be kept around and safe and teachers have the additional workload of connecting it with their computer.

Observation showed little problems in the handling of the digital pen, with only one teacher using the wrong pen for their tasks and only one observer reporting user problems with the synchronization.

B. Viability of static forms in a classroom environment

Multiple problems appeared with the use of the MTTForms that are inherently connected to the DPPT and likely not caused by our form design. One absolutely vital element of the copied pattern approach we used for the

implementation is the send pidget. The user has to hit one of these special form elements with the pen after he or she completes filling a form. If they don't, the form is not transmitted when the pen is in the cradle and the entries of multiple forms may be overlaid on top of each other, rendering all data collected unusable.

This problem arose on 47.2 % of the 36 grading forms we collected after the system was officially introduced at the ISB and in 51.1% of the 90 occasions where the pidget should have been checked on the class book sheets. This indicates that the teachers were not able to use the forms correctly without understanding the underlying problems.

DPPT in the setup we used is restrictive in many areas beyond the pidget issue. Unlike a human evaluator the intelligent character recognition software can only match entered data to a certain subject if the right area for entry is used. Writing outside of text boxes or across lines are unsolvable problems for the software as it is. Computational evaluation of handwriting also requires that the users stick to certain conventions and failing to fill out a certain field or not filling it out correctly can quickly lead to a whole sheet of data being lost.

Further analysis of those 36 grading forms showed more errors that seem based on not understanding the technology: Empty comment fields filled with a dash (9.6%), text corrected directly on the page and not using the correction function (7.3%), text written across the border of input fields (4.5%), and data entered that cannot be understood by the MTT system (6.6%). This did not significantly improve through training.

Training improved those parts of the form usage that were understandable for the teachers, however. In the beginning of the form usage, absent students were marked incorrectly 48.5% (n=65) of the time. This reduced to 8.9% (n=90) in the final phase of testing.

Many of these problems can be avoided by using a unique pattern approach, but this is so expensive in licensing and printing costs that it cannot be used in a large-scale implementation so far.

C. Viability of Text Recognition

The digital pen functions very well when the forms used consist mostly out of checkboxes, recognition here is close to 100%. Text recognition is more of a problem and can be subdivided into two categories for the system provided to us by the bendit GmbH. Text fields can either be based on a white list of words, basically limiting recognition to a dictionary tailored to the application, or on plain character recognition. The first approach is useful for fields that only have a limited amount of words that can be entered into them, such as the subject field in a class book. Technical word recognition rates[6] in these fields approached 90% throughout our tests. Often a figure of 90% would be seen as very low for a character recognition system, and it is in this case as well – considering that it means that every tenth entry into a class book will be unusable this way. However, compared to the free text recognition this is a very high recognition rate. Our results show 62% recognition of words in free text fields and only 45% of numbers in those fields were recognized correctly[7]. These problems are not only based on the intelligent character recognition system we used, but also on the previously mentioned issues of writing outside textboxes or across lines. Still, neither recognition rate is acceptable for a large-scale implementation, rendering the use of DPPT as a whole ineffective unless improved.

D. Benefits of the MTT system in a classroom environment

The MTT System was designed as a tool that saves teachers time and allows them to have a better overview over what is going on in their classes. Especially schools with large classes would profit from the system as the administrative effort rises with the amount of students in a class. The results obtained in the ISB may therefore not be generalized to have a meaning for normal German schools. It can safely be assumed that the benefits of our system are higher in those schools than what we observed in the ISB because teachers cannot stay in contact with a large number of students as well as they can with a small number.

Cleaned time measurements[8] show that teachers took only slightly longer to take attendance with the MTT system (2.8 minutes on average) than they did with their normal system (2.5 minutes on average). This allows the conclusion that the MTT system with fully trained users would be about as fast in attendance tracking as the PC based system the ISB currently uses. Teachers mentioned to us, however, that it takes them a certain time to start up the computer which is obviously not needed for the pen. If the machines used for the PC based attendance tracking stay on all day that is not a problem, but if teachers need to start up the machines every time before they can track attendance, the MTT system gets a strong time advantage.

Further hints at a time advantage were found by other members of the MTT project. Rahamatullah and Trappe performed a survey in various international schools and found out that teachers need, on average, 1 hour and 47 minutes to transfer their grading data to a digital system [13]. This loss of time would almost be eliminated when using MTTWeb.

When asked how they feel about the MTTForms compared to their current system, most teachers found that they were harder to use and that it would take them longer to enter data with the DPPT than normally. This might be due to the fact that the teachers had experience and at least a full day of training with their respective systems whereas the MTT system was relatively new to them.

On the other hand, the majority of the teachers claimed that MTTWeb gives them a better overview over how their students perform than they have now. This is unexpected since the low number of students taught by each teacher should give them good personal contacts to every student. If a school with ten students per class can already benefit from the additional information presented by MTTWeb, normal German schools should gain much more.

[6] A word was counted as incorrect if it was not recognized exactly as it was written on the paper. All words that were still understandable by humans but not technically correct were counted as incorrect.

[7] This evaluation was done on the basis of 100 randomly chosen text fields on the submitted forms.

[8] One outlying measurement was not included in the calculations.

Generally the feedback for the web interface was much better than that for the DPPT. All interviewed teachers could imagine both using MTTWeb regularly for their class administration tasks and using it at home. The general concept of the system seems to be quite understandable for the teachers and many of them added that the idea had high potential and produced interesting results. The only negative feedback collected here that was not directly connected to technical issues of the prototype was that the system only makes sense in larger schools.

One of the reasons for this high acceptance of the web based system is probably that the teachers are already accustomed to using a digital system for their administrative tasks. 75% of the interviewed teachers said that they already used a digital system such as Microsoft Excel® to handle grading. The attendance tracking is fully digital in the ISB now anyway, as mentioned above. It is likely that teachers in other schools are less open to the idea of using a computer based system, as indicated by a few informal interviews we did with German teachers.

IV. Conclusion

Digital pen and paper technology is very promising with regards to classroom administration but has quite a few more hurdles to overcome before it can actually be used. Our testing as well as several other studies showed that the reliability of the collected data is far too low to use it unsupervised. This is not only due to the lacking character recognition but also due to system inherent and technological problems. Advantages in the intelligent interpretation of the strokes collected by the pen could get the technology a lot closer to being useful. More sophisticated software could take context into consideration and for example recognize a stroke that starts inside a box as belonging fully into it, even if the user crosses the border.

A certain understanding of the underlying technology is still needed to avoid mistakes and therefore disproves our assumption that one can simply replace normal pens with digital ones and continue original workflows. At the current state of the technology, extensive training of the users is required, even if they have a considerable understanding of computer technology. Interestingly teachers had more issues with the DPPT than with the web interface – opposing the initial assumption.

That said, the acceptance of the technology in both our study and the results from other scientists has been very good and the end users saw the general idea as a viable solution to some of their problems. Further studies have to be done to find out if DPPT in this form can actually save teacher's time, but the prospects look good. Digital pen and paper technology remains a promising tool that might be made viable through further advancements in interpreting technology.

Acknowledgments

We would like to thank our supervisors Prof. Dr. Andreas Breiter and Dipl.-Inf. Angelina Lange at the University of Bremen for making this project possible through their support and funding and the members of the MTT project for their cooperation.

Additional thanks go to the teachers at the International School of Bremen and their principal whose support allowed us to test the system under real life conditions and the bendit GmbH for providing us with the technical infrastructure we needed.

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