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Understanding the Features of Digital Pen Use in Initial Introductory Lessons

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Abstract: In this paper, we discuss the present state and features of the digital pen, as well as its use in school lessons in Japan; it does so by undertaking an investigation of related systems and research, executing a questionnaire survey, and implementing its use in a real classroom setting. We discuss the Anoto digital pen system while reviewing related research studies; we found some of those studies helpful, as they address the issue of sharing each student's writing and, by extension, reflections on their ideas and thought patterns. We then describe the results of the questionnaire on the use of digital pens before and after lessons. The results revealed that adults tend to have negative images of the system prior to actual use. If learners have such images, teachers should work to counter students' system-use anxieties, in the initial introductory stages; by doing so, learners could find the system attractive and discover its effectiveness. We believe they would understand and appreciate the use of the digital pen, given the causal relationships we discovered through a covariance structure analysis of questionnaire data. Furthermore, these causal relationships were demonstrated in interviews with teachers who suggest that students were most appreciative of the system only when teachers worked to make its use as stress-free as possible.

Keywords: Digital pen system, handwriting, sharing students' writing, real classroom setting, questionnaire survey

Introduction

Since the 1990s, computer rooms in schools all over Japan have been adequately equipped with computers and internet access facilities. Furthermore, even ordinary classrooms have been introducing information and communication technology (ICT) since the 2000s. We call this trend the "electronification of the classroom." We believe that the next stage of innovation in ordinary classrooms is to bring about the electronification of students' pens and notebooks. Addressing these tools is of crucial importance to educational practices, as outlined below. Teachers continually modify learning processes and teaching methods on the basis of formative evaluations, and it is essential that they understand the unique traits of their students and the underlying processes involved in assimilating lesson information. Therefore, we consider that as teachers conduct lessons, they will need to check their students' notebooks, as the information therein would be representative of their thinking processes and their situation *vis-à-vis* the lessons delivered. However, it is difficult for teachers to check the notebooks of all students while a lesson. One of the solutions to this problem is to scan and save students' notes through the use of digital pens, and to review them on a nearby laptop computer or on the projection screen itself. Furthermore, from the viewpoint of the learners, students would be able to more easily reflect, in their writing, their thought processes and ideas by using a digital pen. If students had the option of using a shared notebook system, they could participate in collaborative and interactive learning wherein they could easily read other students' writings and engage in related discussions.

1. Related Work

2.1 Digital Pen System

Our knowledge is primarily of two digital pen systems: the Anoto system and the ultrasonic wave system. However, the balance of the paper focuses on the former.

The Anoto system requires the use of the exclusive paper depicted in Figure 1. Numerous dots are printed on the paper in a special arrangement. An Anoto digital pen can read the dots by using a built-in camera, and it records the handwriting and figures written on it by the users (Figure 2) [1]. Although the Anoto digital pen requires the use of this special paper, no other device is needed.

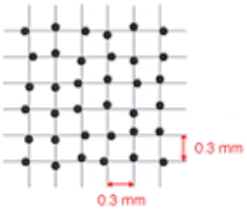

Figure 1 Dot pattern on exclusive paper [1]

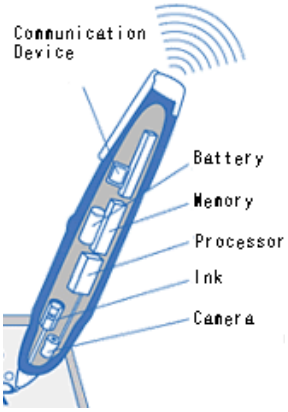

Figure 2 Anoto digital pen system [1]

2.2 Related Research

Some researchers have indicated the benefits of using digital pen technology in education. Kawamura [2] used the digital pen in elementary English classes and reports that the system helped present the ideas of each student; further, the system could convey the written thoughts of students virtually without any delay, and thus helped in carrying out collaborative learning. Finally, the students, of their own accord, were very receptive to the digital pen solution. Wang et al. [3] conducted case studies in three classes at their university and found that the pen-computing environment empowered students and motivated them to acquire knowledge in the realms of the cognitive domain, the affective domain, and communication. Furthermore, it also made learning a more enjoyable experience for the students. It is interesting that the studies undertaken by Kawamura and Wang each highlights the collaborative, interactive, and communicative aspects of learning, which may lead us to consider the enhanced feasibility of collaborative learning when the digital pen system is employed.

Miura et al. [4] developed AirTransNote, a computer-mediated classroom collaboration system that can send a student's handwriting on an ordinary notebook to the teacher's computer by using an ultrasonic wave digital pen system and the services of a personal data assistant device and a wireless local area network. In later years, Miura et al. adopted the Anoto digital pen system and were able, again, to share student handwriting. We consider Miura's research a milestone in the digital pen research field. The four aforementioned studies ([2]–[4]) are helpful in the following ways. They address the subject of the digital pen and its use in classroom settings, and several of them have stated that the digital pen system environment is effective in information-sharing within the classroom; moreover, by using it, learners could communicate with each other in a more comfortable and efficient manner. They also found that the system helped learners review their own handwritten activities and their thinking processes.

Nonetheless, according to our survey results, it seems that learners are unaware of the effectiveness of digital pen systems in the initial, introductory stage of use, and they did not appreciate the technology's potential [5]. This is a little surprise to us, because the digital pen system adapts the traditional learning environment and it seems both problem- and stress-free. We will address and discuss this problem below.

3. Questionnaire on Digital Pen Use before Real Lessons

As part of our plan to introduce digital pen systems to classrooms in Japan, we organized a questionnaire for university and primary-school students. We asked students for their perceptions regarding this proposed introduction to digital pen technology.

3.1 Survey Methodology

The outline of this survey is as follows: The participants included the students of two classes of a course called "Information Literacy Practice 1," delivered at Tokyo Metropolitan University, and one class of a course named "School Education and Multimedia," delivered at Chiba University. In all, 102 university students participated. The survey was carried out on May 8, 2009 and May 6, 2010. Moreover, we also surveyed two sets of primary-school students, in order to compare their responses to those of university students: 27 were from Sakae primary school and another 25 were from Tatsunuma primary school, for a total of 52 primary-school students. The survey was carried out on December 21, 2009 and January 13, 2010. This questionnaire was modeled on another questionnaire that had been designed by the National Institute of Multimedia Education in Japan [6]. First, students watched a three-minute video of a classroom where a lesson was under way and whose students used a digital pen system. This was followed by a formal introduction to the digital pen system. Next, the students filled out our questionnaire on our universities' e-learning systems.

3.2 Survey Results, and Discussion

Table 1 shows the survey results, as well as the items and basic statistics of the questionnaire. The italicized questions are those in which the points have been reversed. The table indicates that the primary-school students' answers ranked significantly higher than those of the university students ($p < 0.01$, except questions 1, 2, 8, and 15).

It seems that adults tend to have negative attitudes toward new ICT tools. Although we have prepared digital pens for researchers and teachers participating in a conference, meeting, and panel discussion—about 20 people in total—nobody used them. We therefore considered the importance of how this technology is introduced to prospective users. How can we improve users' attitudes toward it in the initial stage of use? To answer this question, we performed a covariance structure analysis of our questionnaire data.

Items (each a five-point scale, except question 16)	Prim. Sch. Stu.		Univ. Stu.	
	Mean	S D	Mean	S D
Question 1 The system would be interesting when I use it.	4.06	1.056	4.13	0.792
Question 2 *The system will make me tense when I use it.*	3.04	1.328	3.09	1.234
Question 3 I want to use the system.	4.13	1.010	3.66	1.023
Question 4 The system will be useful for learning.	4.25	0.813	3.40	1.017
Question 5 We can easily learn lessons when we use it.	3.92	0.904	3.01	0.960
Question 6 *Physical pen and paper are better.*	3.15	0.916	2.40	0.882
Question 7 The efficiency of learning will improve when I use it.	3.71	0.977	2.96	0.943
Question 8 *The operation of the system will impose burdens on me.*	2.94	1.243	2.74	1.134
Question 9 *It will be a burden for me as other students will be reading my writing.*	3.29	1.289	2.65	1.078
Question 10 I can enjoy the process of learning when I use it.	3.98	0.828	3.36	0.973
Question 11 I will positively participate in the lessons if I use it.	3.54	0.979	2.85	1.028
Question 12 I will concentrate on the learning when I use it.	3.33	0.993	2.50	0.980
Question 13 *I will worry about the individual information which the system will record.*			3.00	1.072
Question 14 I will be satisfied with the learning when I use it.	3.50	1.038	2.69	0.901
Question 15 I will have a better chance to edit the information when I use it.	3.27	1.097	3.08	1.105
Question 16 Please enter your comments and thoughts.				

Table 1 Results of questionnaire (Points in italicized questions are reversed)

3.2.1 Covariance Structure Analysis

In this subsection, we discuss the causal relationship between the items in the questionnaire, as determined through an analysis of covariance structures. We conducted exploratory factor analysis for 14 items and used the maximum likelihood method to extract the factors. Four factors were extracted when the selection criterion was an eigenvalue ≥1. Table 2 shows the factor pattern of a result conducted by Promax rotation. Correlations among the factors are shown in Table 3. We excluded questions 3, 5, and 6, each of which was a high point in more than one factor and so on; we labeled these four thus: "Appreciate digital pen use in learning" (factor 1), "Effectiveness of digital pen use" (factor 2), "Burden of digital pen use" (factor 3), and "Attractiveness of the digital pen" (factor 4) (Table 3). These four factors were then hypothesized as being latent variables that affected each of the 14 items. These four factors suggest some causal relationship, because there were correlations among them, as shown in Table 3 [7]. First, we assumed that students would find the digital pen attractive only if they did not think that using it would be ineffective; for this reason, we drew a path between "Burden of digital pen use" and "Attractiveness of the digital pen." Second, we supposed that students could determine the effectiveness of the digital pen only if they were attracted to it, and so we drew a path between "Attractiveness of the digital pen" and "Effectiveness of digital pen use." We had been drawing the path figure in this way.

	Fac. 1	Fac. 2	Fac. 3	Fac. 4
Q11 Incentive to study	0.954	–0.109	–0.003	0.07
Q12 Concentration on lessons	0.723	0.045	0.118	–0.117
Q14 Satisfaction in learning	0.709	0.058	–0.045	0.104
Q4 Useful	0.079	0.759	–0.013	–0.034
Q7 Efficiency	0.175	0.637	–0.028	–0.108
Q15 Improve editing skills	–0.056	0.486	0.18	–0.032
Q2 Strain	0.014	0.238	0.855	0.056
Q9 Burden of opening notes	–0.107	–0.012	0.608	0.087
Q8 Burden of operation	0.177	–0.13	0.423	–0.1
Q1 Interesting	0.069	–0.149	0.074	0.952
Q10 Want to use	–0.157	0.449	–0.116	0.413
Q5 Enjoy	0.405	0.2	–0.077	0.303
Q3 Can study easily	0.334	0.507	–0.045	–0.17
Q6 Prefer ordinary pen	0.064	–0.576	0.002	–0.074
Factor contribution	3.584	3.679	1.700	1.827

Table 2 Four factors extracted

	Fac. 1	Fac. 2	Fac. 3	Fac. 4
Fac. 1: Appreciate digital pen use in learning	1.00			
Fac. 2: Effectiveness of digital pen use	0.643	1.00		
Fac. 3: Burden of digital pen use	–0.081	–0.356	1.00	
Fac. 4: Attractiveness of the digital pen	0.214	0.378	–0.349	1.00

Table 3 Correlations among four factors extracted

3.2.2 Checking Goodness of Fit

We verified the correspondence of the variance–covariance matrix between the observed variables and the model (Figure 3), referring to Toyoda's (1998) discussion of how to use the goodness of fit index [8]. We also checked whether or not the path coefficients were significant; all paths were significant ($p < 0.05$). The results of these two goodness-of-fit analyses suggested that Figure 3 could realistically represent the students' understanding structure regarding the appreciation of digital pen use in learning. Therefore, according to the path figure, it is clear that "Burden of digital pen use" affects "Attractiveness of the digital pen," which in turn affects "Effectiveness of digital pen use" and explains "Appreciate digital pen use in learning." That is, students will be attracted to the digital pen system if they are not anxious about its use, and they would thus appreciate it. Therefore, it is important that we as instructors explain, both carefully and adequately, to students that they can use the system easily, choose whether or not to open their notes, and need not be stressed by the use of this technology. Furthermore, teachers should craft their lessons so as to help students understand the efficiency and usefulness of the system, and how it can help them improve their own editing skills. We have to make more such approaches for adult people because they are more skeptical about the digital pen system use than children according to table 1.

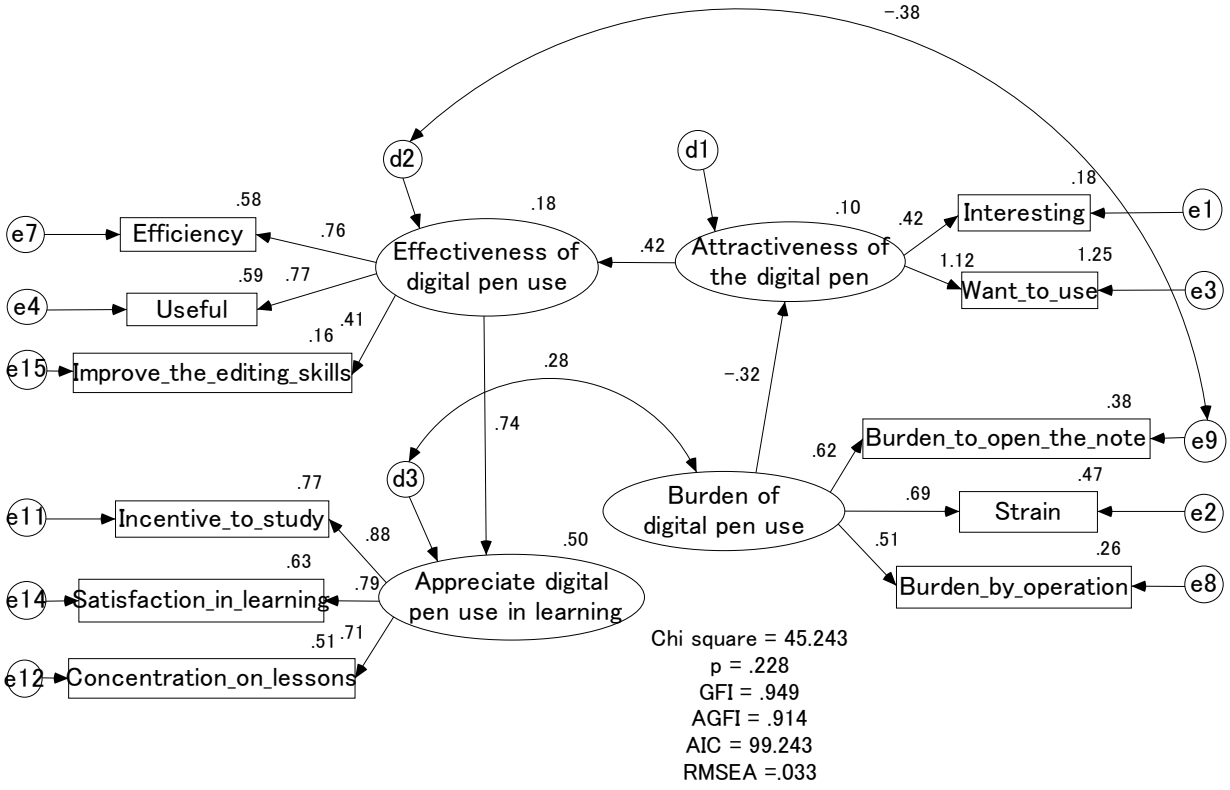

Figure 3 Causal relationships within the structure pertaining to appreciation of digital pen use in learning (Points are not reversed in any items)

*4. D*igital Pen Use in Real Lessons

After executing the questionnaire, we started to implement the use of digital pens in real classroom settings, at two primary schools in Tokyo. All learners used Anoto digital pen systems.

4.1 Implementations in Primary-School Classes

One school was Sakae primary school, whose participants comprised one class of sixth-grade students (n = 27). The subjects included Japanese and

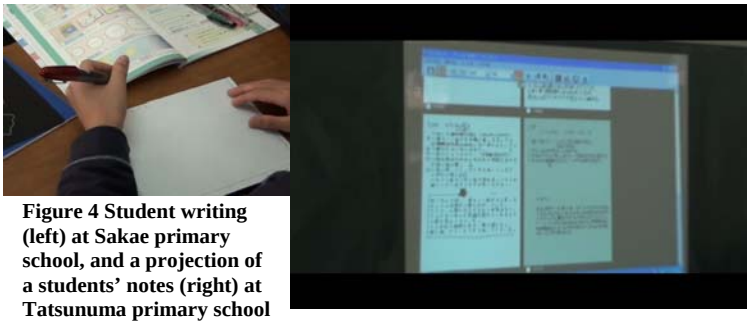

Figure 4 Student writing (left) at Sakae primary school, and a projection of a students' notes (right) at Tatsunuma primary school

arithmetic, among others, and there were 10 separate lessons. The other school taking part was Tatsunuma primary school, whose participants comprised one class of sixth-grade students (n = 31). The subjects comprised Japanese, social studies, and the like, and there were seven distinct lessons. Figure 4 shows scenes from lessons at the two schools.

4.2 Results of the Post-questionnaire and Discussion

We executed a post-questionnaire after the lessons, at each of the schools. The post-questionnaire items were the same as those of the aforementioned pre-questionnaire. Figures 5 and 6 indicate the results of the pre- and post-questionnaires at the two schools. As seen in Figure 5, there were significant differences in questions 8, 9, 10, and 15, between the pre- and post-questionnaires at Sakae primary school. Therefore, we can see improvements in student understanding at Sakae primary school, with regards to "Burden of operation," "Burden of opening notes," "Enjoy," and "Improve editing skills." There were no significant differences among any of the items shown in Figure 6. Therefore, while we considered that the Sakae primary school students might have sustained attitudinal shifts between the pre- and post-questionnaires, such cannot be said of the students at Tatsunuma. The differences between the two schools should be left as the subject of a case study analysis; for the purposes of the current study, however, we must continue to investigate the effectiveness of the system in real conditions and in a number of classrooms over a longer period of time. Furthermore, it is interesting that the plural number of item-points increased with the Sakae primary school implementation, as this result supports our structural equation model (Figure 3). Our model advocates that "Burden of digital pen use" indirectly affects "Effectiveness of digital pen use," and that these items of improvement were observed variables for the two latent variables. That is, it was revealed that the points of the aforementioned observed variables correspondingly increased, and that these increases were explained by the latent variables bearing causal relationships.

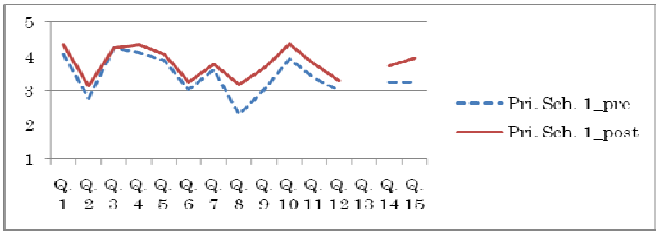

Figure 5 Results of the pre- and post-questionnaires at Sakae primary school (Points are reversed in questions 2, 6, 8, 9, and 13)

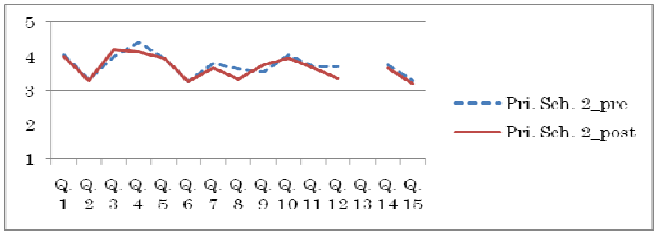

Figure 6 Results of pre- and post-questionnaires at Tatsunuma primary school (Points are reversed in questions 2, 6, 8, 9, and 13)

Therefore, we consider that students are more likely to appreciate the digital pen system when teachers can remove students' feelings of anxiety with regards to it, and that students would be attracted to it and discover its effectiveness through hands-on use in lessons. Finally, the following anecdote demonstrates the efficacy of the anxiety-reduction approach suggested for teachers. The teacher at Sakae primary school said that his students were nervous about using the new technology tools, and he made the effort to tell them that the use of the digital pen was both problem- and stress-free.

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