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A Study of the Utilization of Apple Pencil in the Classroom for Students with Low Vision

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Abstract: Students with low vision make effective use of ICT (Information and Communication Technology) through accessibility settings, and in many cases can use ICT at the same level as able sighted students. In particular, tablets such as the iPad have become an indispensable part of their daily lives and are considered to be one of the tools that can dramatically enhance their learning environment. In this study, we tried to digitize their notes by using iPad and Apple Pencil. Our results showed, the iPad and Apple Pencil were not only effective in the promotion of content understanding and promotion of home study, but also proved usefulness in answering tests. The only ICT used in this experiment was the iPad and Apple Pencil. No other special equipment or environment is required. The only difference is that instead of the conventional form of distributing printed class handouts created by teachers on their PCs the handouts are converted to PDF files and distributed electronically. As for the applications, the standard installed ones are sufficient. Therefore, as long as students and teachers have iPads and Apple Pencils, it is relatively easy to introduce the system, and it is possible to spread the system as a measure for students with low vision. In addition, it is expected that ICT devices such as the iPad and Apple Pencil can be used as an effective support tool for their social participation.

Keywords: Visually Impaired, Low Vision, Apple Pencil, iPad, Tablet Device, ICT Education

1. Introduction

Visual impairment is also known as information disability, and ICT (Information and Communication Technology) plays an extremely important role in education to guarantee the reception of information [1]. There are two types of visual impairment: blindness, in which a person has little access to vision, and low vision, in which a person has limited access to vision [2]. In low vision education, the use of visual aids has become an important issue to be considered in school education, and in recent years, the use of tablets such as the iPad has been attracting attention [2].

The use of ICT, such as tablets, can expand the potential of children with disabilities and play a major role in promoting rational consideration in the future inclusive education system [3]. At the national level, the GIGA school concept, which aims to provide one learning terminal per student and a high-speed, high-capacity communication network in an integrated manner, was approved by the Cabinet in 2019, and the use of ICT is spreading in schools. In addition, with the enactment of the "Act for Partial Revision of the School Education Act, etc." (Act No. 39 of 2018), digital textbooks can be used for students who have difficulty learning with paper textbooks under certain criteria. For students with low vision, access to textbooks has been improved through the use of digital textbooks with text magnification and text-to-speech functions.

Originally, magnifying glasses and magnifying readers were indispensable aids for students with low vision, because it was often difficult to read even the magnified text in paper-based textbooks. Magnifying glasses can be easily carried by each student, but reading magnifiers cannot be

carried everywhere. In addition, not all low vision students have access to a magnifier outside of school. On the other hand, paper-based textbooks for the visually impaired have enlarged text and illustrations, so that a single textbook used in a regular school consists of multiple volumes. Therefore, there are the problems of portability, as these volumes are inconvenient to carry, and operability, where there are difficulties to finding a pages or paragraphs [4]. Even Braille textbooks consist of multiple volumes, which impose similar burdens in terms of carrying and management.

These disadvantages of paper-based textbooks have been eliminated with the advent of digital textbooks, which can store all textbooks on a single tablet. Paper-based textbooks have the "goodness of paper" and it is said that by turning the pages, students can relate information about what is written to where it is written in the textbook, and the content of the textbook can be better absorbed. We will compare the use of paper textbook with those of digital textbooks on tablets to see which has greater merit. Although the perception of each individual varies greatly, in light of the fact that the spread of digital textbooks on tablets is being promoted at the national level, it can be said that there are significant advantages to using digital textbooks on tablets, and that they are a tool that will dramatically improve the learning environment for students with low vision. Digital textbooks are now being widely used for students with low vision, especially in schools for the blind.

There have been many previous studies on the use of ICT in the classroom. In light of the purpose of this study, we will review the research related to the use of tablets in classes for students with low vision.

Kobayashi et al. (2020) [5] pointed out the necessity of using the latest ICT to bring out abilities that have been suppressed due to visual impairment. One example of the latest ICT is the tablet. Among tablets, the iPad comes standard with functions such as voice over, font size enlargement, screen enlargement/reduction, and background/text color inversion as a means of assisting accessibility for the visually impaired [6].

Regarding the actual ICT usage of the visually impaired, Watanabe (2017) [7] reported that the PC usage rate of the blind is 96.7% and 88.9% among those with low vision, the tablet usage rate of the blind is 14.4% and 38.9% among those with low vision, and the smartphone usage rate of the blind is 52.1% and 55.6% among those with low vision. Although the usage rate by age group is not available, it was hypothesized that the usage rate of tablets is low because the sample population ranged from teenagers to those in their 80s. In addition, Watanabe pointed out that the surveys on the use of ICT were concentrated in urban areas, which could be a contributing factor to the stagnating rate of use of tablets in particular. However, there are many opportunities for students in schools for the blind to receive direct instruction from teachers on the use of ICT, including tablets such as the iPad, and it is predicted that the use of iPads is higher than the rate of use reported by Watanabe.

2. Previous Research on iPad-based Teaching

In addition to the widespread use of digital textbooks, the Ministry of Education, Culture, Sports, Science and Technology (MEXT) has developed the "UD Browser" a textbook reading application for the iPad, as part of its "Project to Promote the Use of Assistive Devices and Other Educational Materials for Learning" [8]. In addition, the "UD Browser" has been developed as an application exclusively for the iPad, which shows that the iPad is an optimal tool for learning for people with visual impairments. As for research on classes with digitalized textbooks, Nakano et al. (2014) and Ogura et al. (2014).

Nakano et al. (2014) [9] conducted a survey of students and instructors in a class where both digital textbooks (PDF files installed on iPads) and paper textbooks were available to be used for six months. The results showed that many students wanted to continue to use the digital textbook on the iPad in the future, and that many teachers felt that their students were more motivated to learn than with the paper textbook because they could change the magnification rate and quickly flip the textbook in black and white according to their individual needs. They also reported that there were effects on students' education such as an increase in the number of situations where students actively engaged in research and home study. In addition, Ogura (2014) [10] pointed out the advantages of using iPads, such as the ability to display according to visual acuity, the intuitive operation and ease of use, and the ability to consolidate multiple textbooks and handouts, based on classroom practice using digital textbooks installed on iPads.

As described above, previous studies have shown that digitization of textbooks and handouts is very effective in low vision education. However, at present, educational materials other than textbooks are not necessarily accessible to students with low vision [4]. In other words, the digitalization of teaching materials other than textbooks has not progressed much. Among materials other than textbooks, notes are indispensable for learning together with textbooks. Notes are created by the students themselves. Therefore, although they can be easily digitized by teachers after consultation with students, the digitization of notes has not been promoted on a large scale because it is a matter of individual ingenuity. If notes are prepared for different subjects, the number of notes would be quite large, and the burden of carrying them around and managing them would require further attention. In addition, in order for students with low vision to write in their notes, they need magnifying glasses, reading glasses, and other aids, just as they need to read text in paper textbooks. Following the example of digital textbooks, the use of iPads and Apple Pencils will reduce the burden felt by students with low vision and improve the learning environment. In addition, Ogawa et al. (2021) pointed out that the use of iPads and Apple Pencils is effective as a learning aid for students with low vision [11]. However, with regard to the use of ICT, it is necessary to pay careful attention to ensure the instruction of ICT operation is in accordance with the characteristics each

student of visual impairment so as not to lower the motivation for learning [12]. In light of the above, this study examines the use of the Apple Pencil in classes for students with low vision.

3. How to Use the Apple Pencil

In the past, paper textbooks and paper notes were used in the classroom, which caused problems for students with low vision in terms of transporting them and managing them due to difficulty in seeing. Therefore, by promoting the digitization of notes along with digital textbooks, it is possible to dramatically improve the learning environment for students with low vision. One possible way to digitize notes is to use the iPad and an Apple Pencil, which can be used to write text in PDF files. The iPad (first generation), iPad Air (6th to 8th generation), iPad mini (2nd generation), iPad Air (3rd generation) and iPad mini (5th generation) are all compatible with the Apple pencil. [13].

In order to conduct this study, iPads for teachers and students, and Apple Pencil for students are required. In order to create PDF files, there are multiple methods, one method is to create a fill-in-the-blank class document on a PC and convert it to a PDF file on the PC. There is also a method where the PDF file is created on the iPad itself from the beginning. In either case, it is necessary to save the PDF file on the teacher's iPad in advance for distribution to the students.

Therefore, when a PDF file is created on a PC, it must be saved on the iPad in advance using the following methods. One is to send the file via the cloud, another is to transfer the file by connecting to a PC, and the third is to send the file as an attachment to an e-mail. If the teacher in charge of the class is familiar with these operations, saving the file on the iPad will not be a problem. However, if the teacher is not familiar with these procedures, creating the file on the iPad from the beginning will allow for seamless class preparation.

Through this method, there is no need to distribute paper media because the notes are digitized, and there is no need to connect to a printer to print the tests because they are also digitized. The PDF files stored on the iPads are transferred by AirDrop [14], which is a means of exchanging files between iPads which does not require any special environmental settings. The students open the PDF file they receive in the app, listen to the teacher's explanation, and fill it in using the Apple Pencil, just as they would a paper note.

4. Methods

4.1. Target

We conducted a class with digitized notes using iPad and Apple Pencil for three students (with low vision) in the second grade of a high school for the blind (special needs school for the visually impaired) from June 2020 to March 2021.

4.2. Overview

4.2.1. Lesson

Figure 1 shows an image of a class using ICT. The digitized classes were carried out in a geography and history class. The teacher and the students in this lesson have their own iPads that support Apple Pencil. The students are able to use the iPad in their daily life by themselves with the accessibility settings according to their vision. Based on the actual situation of the students, the class was conducted using the method described in Chapter 3.

4.2.2. Periodic Test

In the same way as with paper notes, the teacher distributed PDF files for the periodic tests, and the students filled them out with an Apple Pencil using the iPad. Students were also asked to submit their answer sheets via AirDrop.

4.3. Understanding of Awareness of ICT Use and Evaluation of Practices

A questionnaire survey and an interview survey were conducted in December of 2020 in order to understand the status of ICT use and awareness of iPad use in the classroom. Because of the small number of students (three), the teachers asked additional questions orally while the students were asked to freely express their opinions on the questionnaire items as a forum for mutual exchange of opinions. In addition, based on the December 2020 survey, an interview survey on the accessibility settings of the iPad was conducted in January 2021.

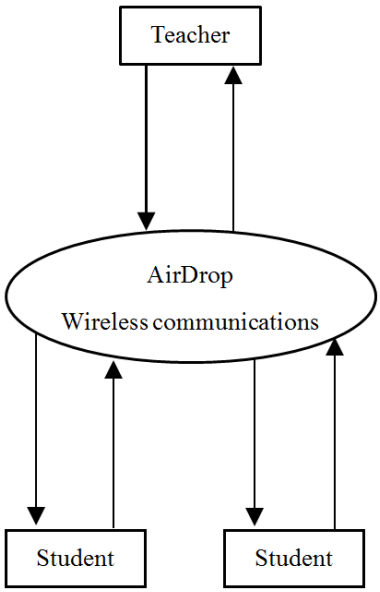

Figure 1. *Image of a class using ICT.*

4.4. Questionnaire Survey Items

4.4.1. Level of Use of ICT

The following items were investigated regarding the level of ICT use.

a. Level of use of Windows, Mac, and Android PCs (4 case method) etc.
b. Level of use of Windows, iPad, Android Tablet (4 case method) etc.
c. Level of use of Windows, iPhone, Android Smartphone (4 case method) etc.

4.4.2. The Effects of Note Digitization

Students were asked how much the digitization of their notes using the iPad and Apple Pencil affected each of the following items.

a. Promotion of content understanding (4 case method).

They were asked to what extent the course facilitated their understanding of the content.

b. Promotion of home study (4 case method).

They were asked to what extent they promoted learning outside the classroom, such as at home.

c. Usefulness in answering tests (4 case method).

They were asked to what extent they found it useful in answering the test.

d. Provision of reasonable accommodation (4 case method).

The question was asked to what extent they felt that reasonable accommodation was provided.

4.5. Interview Survey Items

Based on the questionnaire survey, an interview survey was conducted for the following items in order to obtain further details.

a. ICT application in daily life.
b. Accessibility settings for iPad.
c. Thoughts on digitizing notes with iPad.
d. Thoughts on using the Apple Pencil.

5. Result

5.1. Level of Use of ICT

5.1.1. PC Utilization Level

The results of the survey on the level of PC use are shown in Table 1. 1 of the respondents who had a Windows PC. The mean of the utilization level was 2.33, and the SD (standard deviation) was 0.47. One student had a Mac. The mean of the utilization level was 2.00 and the SD was 1.41. None of the respondent had an Android. The mean of the utilization level was 1.00, and the SD was 0.00.

Table 1. *Level of PC use.*

	Windows	Mac	Android
average	2.33	2.00	1.00
SD	0.47	1.41	0.00

$n = 3$ (4 case method).

5.1.2. Level of Tablet Use

The results of the survey regarding the level of tablet usage are shown in Table 2. As for the tablets, none of the students had a Windows tablet. The mean of the utilization level was 1.00, and the SD was 0.00. Three students had iPads. The mean of the utilization level was 3.67 and the SD was 0.47. No one had an Android phone. The mean of the utilization level was 1.00, and the SD was 0.00.

Table 2. *Level of tablet use.*

	Windows	iPad	Android
average	1.00	3.67	1.00
SD	0.00	0.47	0.00

$n = 3$ (4 case method).

5.1.3. Level of Smartphone Usage

The results of the survey on the level of smartphone usage are shown in Table 3. None of the respondents had a Windows smartphone. The mean of the utilization level was 1.00 and the SD was 0.00. Three respondents had iPhones. The mean of the utilization level was 2.33, and the SD was 1.25. No respondent had an Android smartphone. The mean utilization level was 2.00 and the SD was 1.41.

Table 3. *Level of smartphone use.*

	Windows	iPhone	Android
average	1.00	2.33	2.00
SD	0.00	1.25	1.41

$n = 3$ (4 case method).

5.1.4. Comparison of the Level of ICT Use

The comparison of the level of ICT use are shown in Tables 4 and 5. A two-way analysis of variance of the within-participant design of device (PC, Tablet, Smartphone) by OS (Windows, iOS, Android) showed that the device variable was not significant ($F(2,4) = 0.05, n.s.$). On the other hand, OS variable showed a significant positive correlation ($F(2,4) = 6.05, p < .10$), and the interaction between device and OS ($F(2,4) = 0.05, p < .05$) was significant. Since the interaction was significant, a simple effect analysis showed that there was a significant difference between devices in Windows ($F = 16.00, p < .05$) and OS in tablets ($F = 64.00, p < .01$). Multiple comparisons showed that PC was higher than tablet and smartphone for Windows ($p < .05$), and iOS was higher than Windows and Android for tablet ($p < .05$).

Table 4. *Analysis of Variance.*

S.V.		SS	df	MS	F	
Subj.		7.63	2	3.81		
Device	main effect	0.07	2	0.04	0.05	n.s.
	measurement error	3.04	4	0.76		
OS	main effect	9.85	2	4.93	6.05	†
	measurement error	3.26	4	0.81		
Device × OS	main effect	10.15	4	2.54	4.98	*
	measurement error	4.07	8	0.51		
† $p < .10$ * $p < .05$		38.07	26			

Table 5. *Analysis of Interaction.*

S.V.		SS	df	MS	F	
Device at Windows	main effect	3.55	2	1.78	16.0	*
	measurement error	0.44	4	0.11		
Device at iOS	main effect	4.67	2	2.33	3.50	n.s.
	measurement error	2.67	4	0.67		
Device at Android	main effect	2.00	2	1.00	1.00	n.s.
	measurement error	4.00	4	1.00		
PC at OS	main effect	2.89	2	1.44	1.86	n.s.
	measurement error	3.11	4	0.78		
Tablet at OS	main effect	14.22	2	7.11	64.00	**
	measurement error	0.44	4	0.11		
Smartphone at OS	main effect	2.89	2	1.44	1.53	n.s.
	measurement error	3.78	4	0.94		

$* p < .05$ $** p < .01$

5.2. Effects of Digitization

The results of a survey on the effects of digitizing notes using the iPad and Apple Pencil are shown in Table 6. For the promotion of content understanding, the mean was 4.00, and the SD was 0.00. For the promotion of home study, the mean was 3.00 and the SD was 0.82. In terms of usefulness when answering tests, the mean was 3.67 and the SD was 0.47. With regard to the provision of reasonable accommodation, the mean was 4.00 and the SD was 0.00.

Table 6. *Effects of Digitization.*

	Promotion of content understanding	Promotion of home study	Usefulness when answering tests	Provision of reasonable accommodation
average	4.00	3.00	3.67	4.00
SD	0.00	0.82	0.47	0.00

$n = 3$ (4 case method).

5.3. ICT Applications in Daily Life

The following responses were received regarding the specific use of ICT in daily life. They stated that they could do most of what they needed to do with their iPads, that they used their tablets and smartphones for drawing and research, that they used their PC only for Zoom, and that they used them for communication, transit searches, watching videos, magnifying glasses, and online shopping.

In addition, the following responses were received regarding the difficulties in using ICT. They stated that their fingers would touch and jump to other pages without them knowing, and that the capacity would keep increasing.

In addition, the following responses were received regarding ICT in general. They stated that they rarely use PC because they use iPads on a daily basis, and that they are not sure whether they should buy a Windows or Mac PC when they enter university.

5.4. Accessibility Settings for iPad

The following responses were received regarding the accessibility settings necessary for iPad utilization. First, the "Appearance Mode" of "Screen Display and Brightness" was changed from "Light" to "Dark". This is because the entire screen is too bright for students with low vision, so they set it to "Dark" to reduce the brightness. Next, they turned on "Larger Text" in "Accessibility" under "Screen Display and Text Size" to increase the text size and make the text thicker. However, there were cases where it was difficult to see the text even if the text size was enlarged, and it was also difficult to see application icons, etc., so They turned on "Zoom" in "Accessibility" and set the "Zoom Area" to "Full Screen Zoom". In this way, the entire screen becomes a magnifying glass, and by moving the screen with the touch operation, the desired location is magnified to the entire screen.

All of the above operations are performed from the Settings application of the iPad. In addition, they had set up shortcut keys for "Flip" and "Text Size" in the "Control Center" on the home screen.

5.5. Thoughts on Note Digitization

The following responses were received regarding the digitization of notes using the iPad and Apple Pencil. I would like to be able to use the iPad and Apple Pencil in other classes as well; in mathematics, I use a magnifying reader to check the text of the problem and write notes using the magnifying reader because the problems are listed in the textbook; I would like to hand in items to be submitted in any subject as electronic data using AirDrop on the iPad; PDF files are easier to manage than paper prints. In other classes, he writes the contents of his notes on his iPad outside of class. When studying for tests, he takes pictures of his notes on his iPad, but due to space limitations, he deletes them after the test.

5.6. Thoughts on Using the Apple Pencil

The following responses were received regarding the use of the Apple Pencil. They stated that they use paper-like film, that they can fill in text without any problems, that they can

choose the color and thickness of the text, that it is almost the same as filling in the paper media, that it was good that they could do the test using this method, and that the battery runs out quickly.

6. Discussion

Students with low vision are able to use ICT on their own in their daily lives by setting up accessibility settings such as enlarging text. There are many cases where students with low vision are able to use ICT at the same level as those with normal vision, despite the difficulties caused by their visual impairment. In particular, tablets such as the iPad have become an indispensable tool in daily life because of their large screen size and easy portability. For this reason, iPads should be actively used in the classroom, and digital textbooks using tablets are becoming increasingly popular.

In this study, we engaged in practical classroom methods using the iPad and Apple Pencil to digitize notes, following the digital textbooks. Our results showed the mean values of the following items were high: promotion of content understanding, promotion of home study, usefulness in answering tests, and provision of reasonable accommodation. In the conventional learning style without the iPad and Apple Pencil, students with low vision need to prepare magnifying glasses or magnifying reading devices when they write or read the words in their notes. Magnifying devices are particularly expensive and large in size, so they cannot be easily carried around on a daily basis.

By digitizing notes using the iPad and Apple Pencil, students will no longer need an expensive magnifying reader, and will be able to study anywhere with just the iPad and Apple Pencil. In other words, students with low vision will be able to study in the same way that sighted students study in their daily lives. For example, they can use the iPad to study on the train on their way to school, just as sighted students open their notes. In this way, students with low vision will be able to study almost the same as sighted students with sighted eyes, which will reduce the difficulties caused by visual impairment and increase their motivation to learn. Therefore, the digitization of notes using the iPad and Apple Pencil is considered to be a rational consideration for students with low vision, leading to an increase in study time and a direct link to content understanding.

In addition, the use of the Apple Pencil is “Almost the same as writing on paper.” It can be said that the digitalized notes are more convenient for students with low vision than the paper notes. In the test, the students were able to use the iPad and the Apple Pencil as usual, which may have made it easier for them to answer the questions. However, we also received some responses such as “The page jumps.” Therefore, teachers need to pay special attention to this point when using iPads in the classroom.

The only ICT used in this experiment was the iPad and Apple Pencil. No other special equipment or environment is required. The only difference is that instead of the conventional form of distributing printed class handouts created by teachers on their PCs the handouts are converted to PDF files and distributed electronically. As for the applications, the standard installed ones are sufficient. Therefore, as long as students and teachers have iPads and Apple Pencils, it is relatively easy to introduce the system, and it is possible to spread the system as a measure for students with low vision.

In addition, as the GIGA school concept progresses, tablets will become standardized teaching equipment, and the use of ICT such as tablets will become more and more widespread both in schools for the blind and in regular schools (elementary schools, junior high schools, high schools, etc.). In light of this, at least for the digitization of notes in this study, there will be no significant difference between schools for the blind and normal schools, and there is a possibility that classes conducted in normal schools can be introduced in schools for the blind. In such a case, it will be necessary to take into account the characteristics of visual impairment as a rational consideration, but it will lead to the elimination of the boundary between schools for the blind and regular schools, and it will contribute to the construction of an inclusive education system, which is a system in which people with disabilities and people without disabilities learn together.

The results of the analysis of variance show that Windows is the most commonly used PC and iOS (iPad) is the most commonly used Tablet. Looking at the global share rate (January of 2021 to January of 2022), Windows is 74.82%, iOS is 16.02%, and Android is 2.11% for PC, and iOS is 55.46%, Android is 44.44%, and Windows is 0.06% for Tablet [15, 16]. Therefore, the visually impaired, who are the subjects of this study, tend to match the general population in this regard. In other words, they are not in a special environment.

In this study, we examined the use of the Apple Pencil, based on the survey results, it can be said that the iPad should be selected as the device to be used as the iPad generally is preferred when introducing ICT devices to those who need support. In addition, since there was no difference in the level of utilization between the devices, it is necessary to explore new methods, such as allowing the use of the Apple Pencil even for Macs, which are Apple products, and support using Windows devices, which are incompatible with the Apple Pencil, when selecting a PC as a device to support them.

7. Conclusion

Hamada et al. (2019) [2] pointed out that there is not sufficient data on the effects and issues of ICT in low vision education at present. With regard to the spread of ICT use, Hotta et al. (2008) [17] pointed out that it is necessary to present typical class situations in which ICT is used, and for each teacher to select one that is easy to incorporate into his or her own teaching style, and to actually try it out in his or her own class.

In light of the above, further experimentation and research on the use of ICT for students with low vision must be carried out in the future. In order to achieve this, all teachers, regardless of their ability to use ICT, and regardless of whether they have a

special environment or not, must be involved in the use of ICT in the classroom. In this sense, this study was able to present a practical example of a class that is easy to introduce and has great advantages for students with low vision. In the future, it is expected that ICT such as the iPad and Apple Pencil will be actively used as effective support tools to the participation of people with low vision or impaired in society.

In this study, there were only three test subjects, which is a small and rather unrepresentative number. Therefore, further research with larger sample sizes is necessary to verify the results. In addition, in order to make the use of ICT, such as iPad, the standard in low vision education in the future, it is necessary for teachers involved in low vision education to know that ICT is a tool that can dramatically improve the learning environment for students.

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