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Investigating E-Learning Accessibility for Visually-Impaired Students: An Experimental Study

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STEM education has long been recognized as the foundation for national competitiveness and future prosperity. In STEM, mathematics serves as the key to other areas (science, technology and engineering). Existing evidence shows that an integrated curriculum in mathematics enhanced the majority of students' performances on standardized tests. However, many visually-impaired students seem to fail to reach proficiency in mathematics. In this paper, we present a new approach to promote vision-impaired students' overall math performance and enrich their learning experiences. We first investigated student learning difficulties and then developed a new mathematics curriculum with the integration of the Digital Accessible Information System (DAISY). This curriculum mainly addresses DAISY-compliant electronic textbooks that can be displayed on a Non-Visual Desktop Access (NVDA) screen reader. Finally, we conducted an experiment in order to evaluate the effects of the new teaching approach. The experiment included a four-day pedagogical program and an assessment session. Specifically, the test focused on students' mathematics scores and their NASA-TLX subjective mental workload. The findings showed that the value of the NASA-TLX subjective scales ($t = 4.271$, $p < 0.05$) was significant and the student accuracy rate increased. Thus, we conclude that this new method effectively improved vision-impaired students' proficiency in mathematics.

Keywords: visually impaired students; curriculum development; e-learning; usability testing; DAISY

1. Introduction

STEM stands for Science, Technology, Engineering, and Mathematics. STEM education has become the focus of secondary and higher education due to its influence on a nation's economic prosperity. President Obama remarked that 'Leadership tomorrow depends on how we educate our students today—especially in science, technology, engineering and math' [1]. 2015 financial budgets on STEM education raised up to $2.9 billion [2] in order to promote the national competitive advantages in innovation. In 2014, STEM-related jobs made up at least 20% of the total workforce in the United States [3]. Several STEM organizations such as STEM Master Teacher Corps, or Integrated Curriculums have started supporting students in STEM education.

For students with visual impairments, various types of mathematics textbooks have been published in order to meet students' special needs. The current assistive publications include Braille textbooks, human-voice audio-books and large-print textbooks. However, these three types of textbooks are not cost effective and their production processes are time consuming. Other remaining problems are related to the efficiency for updating contents. Therefore, we created new DAISY mathematics textbooks with better accessibility and productivity.

In this new digital era, many specialized technologies exist in order to help disabled students access and learn new knowledge. Electronic learning (E-learning) software and electronic books (e-books) are innovative tools that are frequently used in educational contexts. More specifically, a DAISY book has been developed for assisting people with visual impairments [4]. Another useful tool employed in this study is the Non-Visual Desktop Access (NVDA) tool, which is a free software screen reader. It can help visually-impaired students navigate a computer during self-directed learning. In addition, we included another computer program, Adaptive Multi-Media Information System (AMIS), in this study in order to help students successfully activate DAISY eBooks.

This study aims to incorporate these assistive technologies in the design of a new learning approach to students with visual impairments. The process of the present study is illustrated as follows: (1) we first converted a PDF electronic textbook to a DAISY e-textbook, and then (2) we employed a usability test to assess the students'

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learning performance. It is hoped that visually-impaired students could improve their math scores after the use of the DAISY e-textbook.

2. Literature review

2.1 Mathematics education for visually-impaired students

Mathematics is one of the fundamental subjects in the STEM curricula because it is the basis for other related fields such as science, technology and engineering [5]. However, many mathematics concepts are too abstract for visually-impaired students to understand. At the same time, the published standard for regular mathematics textbooks is time-consuming, and publishers often encounter difficulty when editing and updating the content. More importantly, the math grades of students with visual impairments are often unsatisfactory in comparison with those of the majority of students.

Current mathematics textbooks for visually-impaired students can be divided into two categories: (1) Braille textbooks that are audio-books (with a MP3 format) designed for blind students, and (2) textbooks in large print designed for moderately vision-impaired students.

There are some shortcomings that might render the learning process regarding these two types of textbooks. For example, large-print textbooks cannot meet every individual need since each visually-impaired student may require different font sizes. Meanwhile, certain mathematical texts, charts or formulas cannot be accurately expressed in Braille textbooks. Furthermore, as previously discussed, it is very challenging for instructional designers to update the contents of these two kinds of publications.

2.2 E-learning

Electronic Learning (E-learning) incorporates a wide range of computer-based programs and educational materials [6]. Compared to traditional learning methods, E-learning has two major advantages. First, a computer can be patiently tolerant toward a relatively long reaction time and does not criticize the users' task performance. Therefore, students are more likely to learn math by trial and error in a computer-mediated environment. Secondly, students are able to take e-learning lessons several times in a computer-based setting [7]. In terms of these two major benefits, several researchers have conducted e-learning studies. For example, Ecalle et al. [8] recently proposed a specific e-learning system that supports low-level children in the development of their word recognition and reading comprehension. Other two examples of the application of e-learning include: (1) Krajnc [9], who used the e-learning system in the chemical engineering educational process, and (2) Yücel Uğurlu [10] who enhanced human–computer interactions by e-learning.

2.3 Digital Accessible Information SYstem (DAISY)

DAISY is a technical standard for digital audio books. It was viewed as a potential audio substitute for paper-based materials. DAISY books were designed for handicapped people with reading difficulties across a wide spectrum, including blindness, visual impairments, and dyslexia. The DAISY Consortium was developed in 1996 in order to promote a new digital talking-book standard based on the original DAISY concept. The DAISY standard has been widely employed in e-books, especially those developed for the visually-impaired [4].

Many books, magazines, newspapers and documents have been converted to the DAISY format. For example, *Physical Review Letters*, a prestigious academic journal in the field of physics, has been transformed into DAISY format [11]. The American non-profit organization Bookshare.org offers more than a quarter-million DAISY-converted books for free download [12]. The Royal New Zealand Foundation of the Blind (RNZFB) committed itself to promoting DAISY e-books and has applied it to the Foundation's library [13]. The German Leipzig Central Library started converting its collection to the DAISY format from other audio formats in 2010 [14]. The Canadian National Institute for the Blind (CNIB) Library has also adopted the DAISY format and used it to convert taped publications into digital ones [15].

In Taiwan, National Tsing Hua University, National Changhua University of Education Library, Tamkang University and the Taiwan Digital Talking Books Association have a large collection of e-books that are available for free download. Unfortunately, none of these digital sources contain DAISY textbooks.

The use of DAISY e-textbooks for learning mathematics has four advantages. First, DAISY e-textbooks can maintain the original contents during the translation process. Second, DAISY e-textbooks can provide visually-impaired students with detailed auditory or tactile information on mathematics formulas and figures. Third, the playback device embedded in DAISY books can allow users to adjust the contrast and font sizes of texts. Fourth, the playback tool is compatible with Braille display elements. More importantly, this innovative playback technique can help users to better recognize and comprehend mathematics symbols and formulas.

2.4 Usability testing

According to the International Organization for Standardization (ISO) 9241-11, usability is defined as 'The extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use' [16]. Ergonomics experts further defined usability testing as a metric to measure the interactions among users, software products, and hardware equipment [17]. Methods of usability testing include questionnaires, interviews, and performance measurements [18]. For example, Alelaiwi and Hossain [19] used the usability testing to evaluate user interfaces for engineering education tools. In order to identify usability problems and improve user-friendliness, users were often video-recorded during task performances when they performed typical tasks with a software tool [20].

Kahneman [21] observed that mental workload is directly related to the proportion of the mental capacity a user spends on a task performance. Mental workload assessments can provide insights into how mental efforts are made to accomplish tasks [22]. The National Aeronautics and Space Administration Task Load Index (NASA-TLX) was designed in the 1980s by NASA's Human Performance Group. The NASA-TLX is viewed as a generalizable tool for measuring subjective mental workload. It has been employed extensively in studies involving human performance [23]. The NASA-TLX is a multidimensional assessment technique that depends on a multifaceted construct to obtain overall workload scores. NASA-TLX measurements are based on a six-dimension scale: mental demand, physical demand, temporal demand, performance, effort, and frustration levels. Each subscale contains a numerical rating from 0 points to 100 points [24, 25].

2.5 Summary

Based on our literature review, we found that DAISY e-books could be very beneficial. However, to date, no mathematics e-textbooks have been used in special education. Therefore, this study develops a DAISY mathematics e-textbook for students with visual impairments. Furthermore, this study used the usability testing as the evaluation criteria for determining the effectiveness of our new e-learning approach. Our goal is to provide an alternative method to help visually-impaired students overcome their learning problems and to improve their academic performance in mathematics.

3. Methodology

The purpose of this study was to develop and evaluate a new e-learning approach to teaching mathematics to students with visual impairments. In order to better understand the mathematic performance and learning difficulties of our participants, we designed a questionnaire and conducted individual interviews. Moreover, we developed a new learning method based on the interviews and questionnaire responses. Subsequently, we conducted an experiment in order to assess the effects of the new learning method. The research method is discussed in detail in the following section, and the research procedure is shown in Fig. 1.

In 2013, 254 visually-impaired students enrolled in a junior high school in Taiwan [26]. Although the population of the visually-impaired students was low in comparison to the entire student population, we still needed to ensure that secondary students with visual impairments can be well-prepared for their future study. According to the TSETN 2013 data, the mathematics performance of these students was below the national average in Taiwan. This phenomenon may result from a lack of learning resources and assistive tools to accommodate visually-impaired students' special needs.

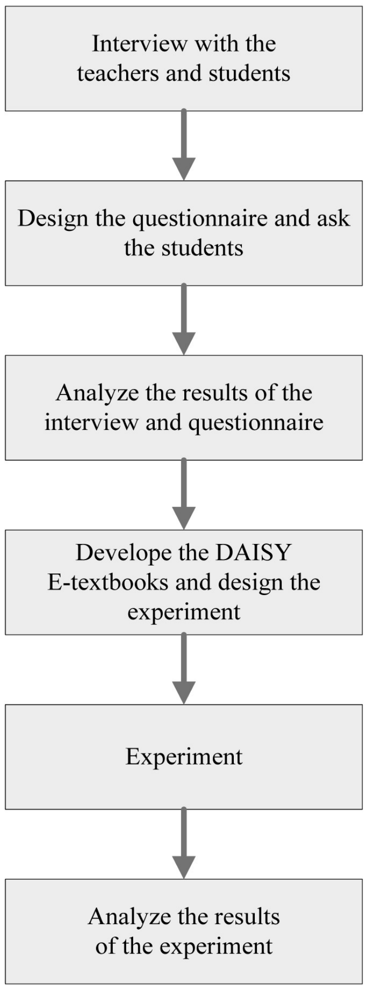

Fig. 1. Research process.

3.1 Curriculum development

We conducted in-depth interviews with four participants: two teachers who worked with students with visual impairments for 40 years and two visually-impaired college students. The interview questions inquired about the difficulty of learning mathematics.

Moreover, based on the learning attitude scales developed by scholars in Taiwan [27–29], this study designed a questionnaire to investigate the learning environment for students with visual impairments. The questionnaire was divided into three parts: Individual learning attitudes, The use of assistive tools, and The mathematics learning environment in Taiwan. The questionnaire presented 34 questions and consisted of a 5-point Likert rating scale: Strongly disagree, Disagree, Neutral, Agree and Strongly agree, shown in the Appendix.

To develop the materials, this study first collected secondary mathematics textbooks from the National Institute for Compilation and Translation in Taiwan. These textbooks were then converted into DAISY e-textbooks. The mathematical formulas and graphics became text descriptions in the DAISY e-textbooks. Next, this study used HTML to edit the text descriptions. These descriptions were supportive materials that can be presented in screen reader programs or in Braille devices. This type of text description was an explanation of a mathematical formula, and it was developed by highly experienced math teachers and content experts.

3.2 Experimental design

Once the e-textbook was developed, this study organized a four-day experimental mathematics program to evaluate student learning performance. This experiment compared the use of traditional Braille textbooks to the use of the DAISY e-textbooks. These two learning approaches were independent variables. The dependent variables consisted of the NASA-TLX subjective scales, reaction times, and student accuracy rates.

3.2.1 Participants

Twelve visually-impaired students participated in the four-day mathematics program. All participants possessed the basic ability to operate a computer and were familiar with the computer keyboard layout. All of the participants were junior high school students. Nine students had severe visual impairments and three had moderate visual impairments.

3.2.2 Experimental equipment

Non Visual Desktop Access (NVDA) is a free screen reading tool that served as e-learning software in our experiment. NVDA allows blind or vision-impaired users to navigate and employ desktop applications. It also can read out text from the screen, such as buttons, menus or menu items. Its text-to-speech output is verbalized via synthetic speech, which is available in over 40 different languages, including Chinese. In this study, each visually-impaired student had a computer and a microphone that helped him/her engage in self-learning. Figure 2 illustrates a participant who used this experimental equipment.

Fig. 2. The experimental equipment and environment.

3.2.3 Experiment process

First, the questionnaires were completed and collected. Next, the participants attended a four-day course. This study recruited an itinerant teacher who provided visually-impaired students with mathematic instruction by using DAISY e-textbooks. In addition, this study also recruited a visually-impaired computer teacher to teach the e-learning software. During the four-day program, participants learned and answered math questions via DAISY e-texbooks.

After the program, this study assessed the learning achievements of the participants through a mathematics exam. In order to directly compare the use of traditional Braille textbooks with the use of DAISY e-textbooks, we divided the participants into two groups (A and B). Finally, the participants were asked to determine the NASA-TLX subjective scales and complete open-ended questionnaires. Figure 3 shows the experimental process.

4. Results

4.1 Curriculum development

4.1.1 Questionnaire responses

All thirty-two visually-impaired students completed the questionnaire. Students came from different

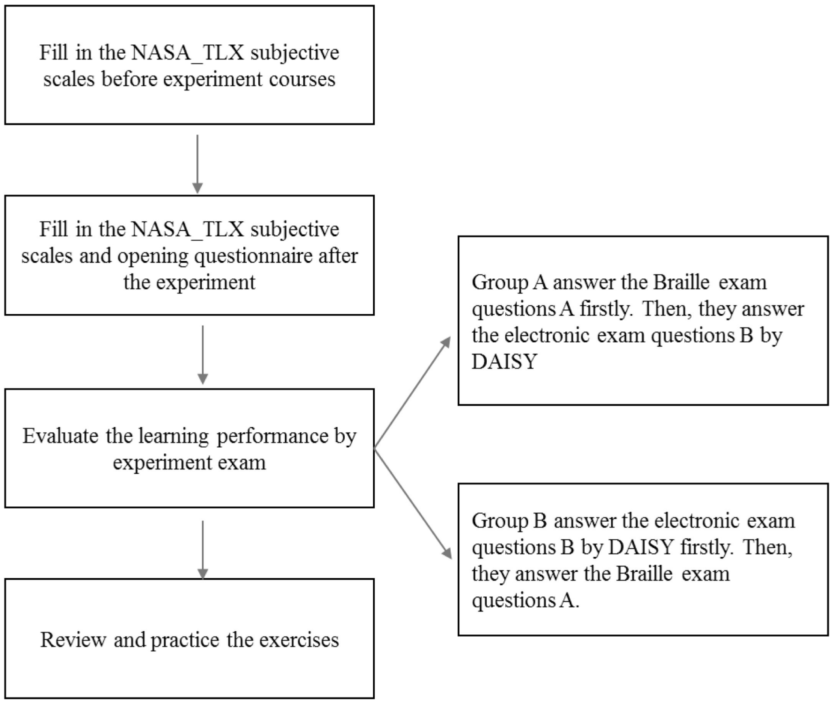

Fig. 3. Experimental process.

regions of Taiwan, from the northern to central areas. Participants included 14 male students and 18 female students. Twenty students were severely visually-impaired, ten were moderately visually-impaired, and two were slightly visually-impaired. This study used the SPSS® 15.0 program to analyze student answers. The statistical analysis showed that the Cronbach's alpha score for confidence was 0.847. Also, the findings showed that the value of the reliability coefficients was over 0.6, which was considered adequately reliable, as stipulated in Nunnally and Bernstein's study [30].

In the light of questionnaire responses, this study found that the participants lacked motivation for learning mathematics. Moreover, students seemed unwilling to prepare for mathematics exams and their grades were comparatively low. Accordingly, their capability of understanding mathematical formulas and graphics were below average. A few parents even hired private tutors to work with their visually-impaired children. Moreover, this study also discovered that teachers and parents rarely used assistive devices or tools to facilitate students in learning mathematics. This indicated that additional learning resources might be required. The only positive response was that many visually-impaired students had good interactions with their math teachers.

In summary, the questionnaire responses showed that visually-impaired students in junior high school faced great learning difficulties. There was an urgency to create a better mathematics educational environment for visually-impaired students by introducing advanced assistive devices or alternative learning approaches.

4.1.2 Interview results

In order to better understanding mathematics learning difficulties for visually-impaired students, we conducted deep interviews with two teachers of students with visual impairments and two visually-impaired university students. One student studied in the Department of Atmospheric Science at the National Taiwan University and the other studied in the Department of Computer Science at the National Tsing Hua University in Taiwan. These four interviewees suggested that mathematic characters and symbols could be presented through vocal expressions because visually impaired students should be comfortable with screen reader software.

4.2 Experimental results

This study used the examination times and student accuracy rates as performance indicators. In addition, the participants completed the NASA-TLX questionnaires before and after the pedagogical program. We analyzed these data by using SPSS® 15.0.

Table 1 indicates that the findings of NASA-TLX subjective scales were significant ($p < 0.05$). The visually-impaired students learned better by using the DAISY e-Textbook. The students also had lower mental workloads when compared to the

Table 1. NASA-TLX scores compare results

Format	Average ($n = 12$)	*SD*	*T*	*p*
Braille	1191.67	191.89	4.271	0.01**
DAISY	882.92	133.92		

$^{**}p < 0.01$.

Table 2. Correct rate analysis results

Format	Average ($n = 12$)	*SD*	*T*	*p*
Braille	0.47	0.33	–5.742	0.00***
DAISY	0.72	0.28		

$^{***}p < 0.001$.

Table 3. Answer times analysis results

Format	Average ($n = 12$)	*SD*	*T*	*p*
Braille	958.17	295.24	1.963	0.75
DAISY	792.83	288.15		

other group, with the use of the Braille textbooks. The results also showed that the completion time for the quiz was not significant ($p > 0.05$). However, student accuracy rates were significant ($p < 0.05$) as shown in Table 2. This indicates that the DAISY e-textbooks provided the participants with a better learning opportunity. Finally, answer times were not significantly different between the two groups (as shown in Table 3), since most of the students spent the same amount of time on the task.

5. Findings and discussion

5.1 Findings

It is interesting to note that one of the participants had only one error on the test. The reason for this error was because the participant misread the Braille test question from $3(x - 5)$ (Fig. 4) to $-(x - 5)$ (Fig. 5). In other words, a slight difference exists between these two equations regarding their

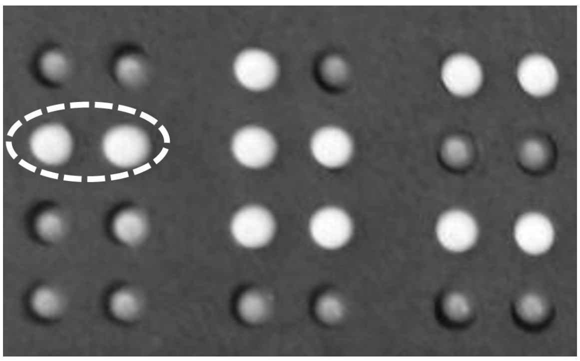

Fig. 4. Mathematical formulas $3(x - 5)$ in Braille.

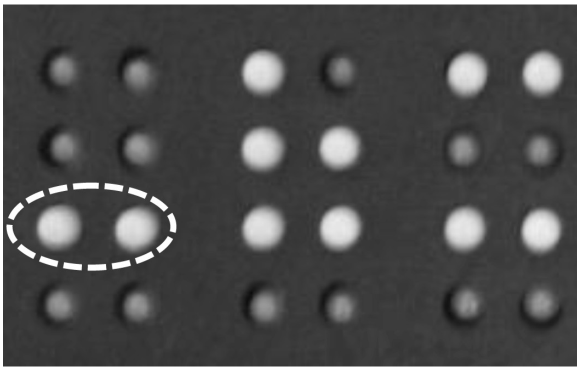

Fig. 5. Mathematical formulas $-(x - 5)$ in Braille.

spatial display in Braille. A minus sign is located at the third and sixth points in Braille. On the other hand, number three is placed at the second and fifth points, which is one line above. If the participant had heard the question, the error could have been avoided.

During the experimental program, the participants also learned the operation procedures of the computer and the screen reader in addition to mathematics. A specialized keyboard that contained an anchor point and Braille had been created as an assistive tool to help the students to navigate computer programs (Fig. 6 and Fig. 7). Moreover, featured-color keyboards could support persons with amblyopic disorders to work with the computer.

Even though the participants were using the screen reader for the first time, they were able to coordinate that effort with the Braille textbook or with the Chinese Braille display. Many participants indicated that the screen reader helped them to navigate texts more easily, especially for the functions of 'forward to chapter' and 'paragraph.' These functions efficiently assisted participants in finding relevant information.

Finally, many participants commented that they were willing to participate in this pedagogical course because they could not only learn mathematics but also learned e-learning tools. More specifically, they could learn how to use a computer and a screen reader. They could apply these technologies to their own study. Therefore, we concluded that this new learning method successfully promoted the visual-impaired students' autonomy and motivated them to learn mathematics.

5.2 Discussion

According to the experimental results in Table 3, both Braille and DAISY groups spent the same amount of time on the test. It might be because students were familiar and comfortable with the Braille format in studying their usual textbooks.

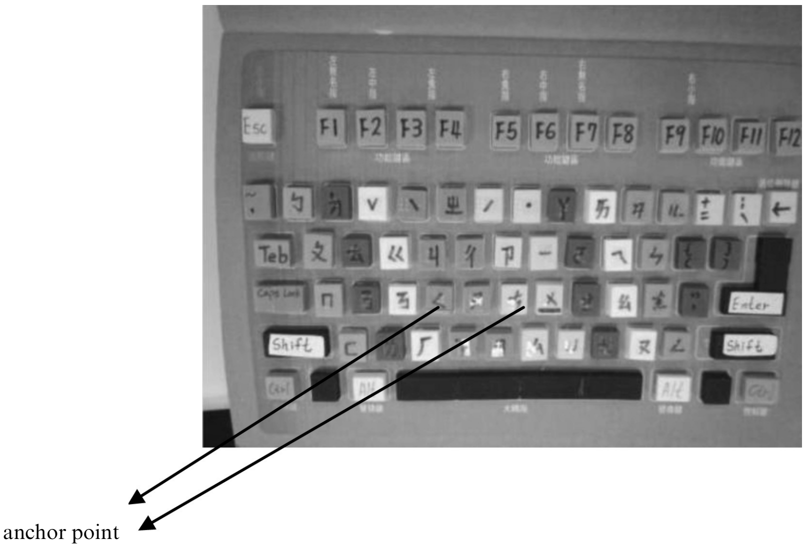

Fig. 6. Computer keyboard.

After the pedagogical program, the visually-impaired students, their parents and math teachers began to adopt the NVDA in their learning and teaching processes. This phenomenon strongly suggests that students, parents and teachers have fully accepted this e-learning approach and relevant assistive technologies in learning mathematics. In addition, the screen reader is commonly used at libraries in many countries [31–35]. However, it has not yet been employed as a learning tool for persons with visual impairments.

Similarly, DAISY has also been widely used in a variety of publications, such as books, magazines and newspapers at many libraries worldwide; however, the DAISY system has not yet been applied to textbooks. To date, the major learning methods for visually-impaired students have involved teacher lectures and Braille textbooks. Braille textbooks can be cumbersome and have insufficient regard to their contents.

This study proposed a new learning method with the use of DAISY e-textbooks. In particular, DAISY e-textbooks have the capability to integrate human voice narrations with digital texts, offering the great advantages of learning mathematics. For example, mathematic contents can be presented via the voice software and screen reader.

This method has been approved to be helpful for visually-impaired students in learning mathematics. Our new learning method also significantly reduced the mental workload of the visually-impaired students. More importantly, student accuracy rates increased. Therefore, we believe that this new learning approach with the use of DAISY technology can enhance the learning of mathematics and can be extended to other STEM-related subjects, such as physics and chemistry.

5.3 Limitations

In the experiment, our sample size was relatively small and the computer familiarity of the participants was not the same across the entire sample.

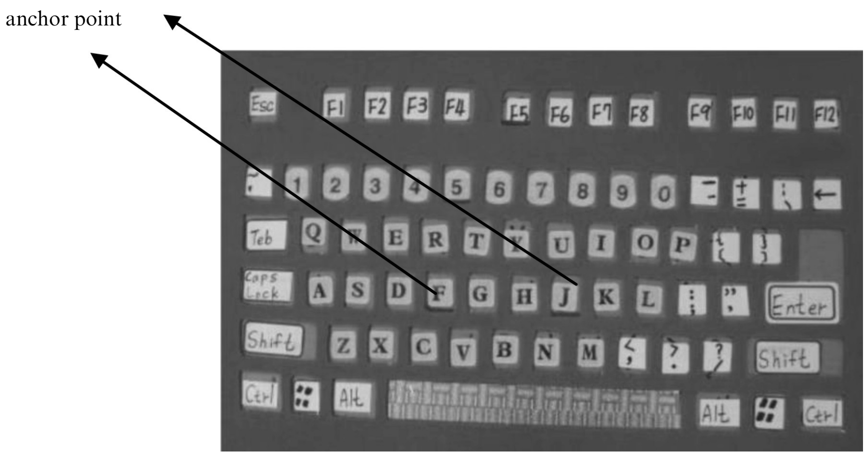

Fig. 7. Computer keyboard.

This factor might influence the answer time (between the Braille format and DAISY format). In addition, combining the differences in students' mathematics capabilities with their distinct learning attitudes, it is understandable that the results could be radically affected by individual differences.

6. Conclusions

6.1 Conclusion

Conventionally, visually-impaired students learn mathematics through Braille textbooks. This study proposed a new method to assist students with perceptual disabilities in learning mathematics by using DAISY e-textbooks. These e-textbooks include all mathematics contents that can be presented in Braille textbooks and can operate in the NVDA device. Our results indicate that DAISY e-textbooks helped participants advance their test scores when compared to another learning approach (i.e., Braille textbooks). Thus, this new learning method can successfully improve visually-impaired students' mathematics competencies. We concluded that DAISY technology should be incorporated into the development of other STEM curricula in order to facilitate visually-impaired students in learning related subjects.

6.2 Future research

A future study can focus on the development of DAISY e-textbooks for other engineering subjects. Visually-impaired students may benefit from these DAISY-based learning materials. Moreover, this study focused primarily on students with visual impairments in junior high school. A future direction can address visually-impaired students in senior high school or college-level mathematics/ engineering courses in order to better support engineering education.

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References

1. Remarks by the President on the 'Educate to Innovate' Campaign and Science Teaching and Mentoring Awards (2010). http://www.whitehouse.gov/the-press-office/remarks-president-educate-innovate-campaign-and-science-teaching-and-mentoring-awar, accessed 15 July 2014.
2. *Preparing Americans with 21st Century Skills. Science, Technology, Engineering, and Mathematics (STEM) Education in the 2015 Budget*, 2014, http://www.whitehouse.gov/sites/default/files/microsites/ostp/Fy%202015%20STEM%20ed.pdf, accessed 15 July 2014.
3. The official website of STEM Education Coalition, 2014, http://www.stemedcoalition.org, accessed 15 July 2014.
4. B. G. Whitehouse, Access to books for the visually impaired: moving from charity to choice. Loughborough's Institutional Repository, 2011.
5. C. S. Lin, The basic philosophy of mathematics education, Department of Mathematics, National Taiwan monograph column, 2009.
6. http://www.math.ntu.edu.tw/community/viewtopic.php?-CID=7&Topic_ID=48, accessed 15 July 2014
7. A. Karaksha, G. Grant, A. K. Davey and S. Anoopkumar-Dukie, Development and evaluation of computer-assisted learning (CAL) teaching tools compared to the conventional didactic lecture in pharmacology education, *EDULEARN11 Proceedings*, 2011, pp. 3580–3589.
8. M. Schittek, N. Mattheos, H. C. Lyon and R. Attström, Computer assisted learning. A review, *European Journal of Dental Education*, **5**(3), 2010, pp. 93–100.
9. B. A. Weisbrod and E. D. Asch, The truth about the 'crisis' in higher education finance, *Change*, **42**(1), 2010, pp. 23–29.
10. J. Ecalle, N. Kleinsz and A. Magnan, Computer-assisted learning in young poor readers: the effect of grapho-syllabic training on the development of word reading and reading comprehension, *Computers in Human Behavior*, **29**(4), 2013, pp. 1368–1376.
11. M. Krajnc, E-learning environment integration in the chemical engineering educational process, *International Journal of Engineering Education*, **25**(2), 2009, pp. 349–357.
12. Y. Ugurlu, Smart e-learning: enhancement of human–computer interactions using head posture images, *International Journal of Engineering Education*, **29**(3), 2013, pp. 568–577.
13. J. Gardner, V. Bulatov and R. Kelly, Making journals accessible to the visually impairedvisually-impaired: the future is near. Learned publishing, *Journal of the Association of Learned and Professional Society Publishers*, **22**(4), 2009, p. 314.
14. A. Palo Bookshare celebrates major milestone: 100,000 students: exceeds target & serves more students, 2010, https://www.bookshare.org/_/aboutUs/2010/10/100kStudents, accessed 15 July 2014
15. G. Morgan, A word in your ear: library services for print disabled readers in the digital age. *Electronic Library*, **21**(3), 2003, pp. 234–239.
16. German Central Library for The Blind, Who we are and what we do, 2011, http://www.dzb.de/en/about-us.html, accessed 15 July 2014
17. S. Paterson, CNIB library for the blind: placing library service for the blind in the community, 2011, http://www.coll ection-scanada.gc.ca/accessinfo/005003-3020-10-2001-e.html, accessed 15 July 2014
18. ISO/IEC. 9241-14 Ergonomic requirements for office work with visual display terminals (VDT)s—Part 14 Menu dialogues, ISO/IEC 9241-14: 1998 (E), 1998.
19. J. Nielsen, *Usability Engineering*, Morgan Kaufmann, San Francisco, 1993.
20. A. Alelaiwi and M. S. Hossain, Evaluating and testing user interfaces for engineering education tools: usability testing, *International Journal of Engineering Education*, **30**(3), 2014.
21. M. B. Rosson and J. J. M. Carroll, *Usability Engineering [Electronic Resource]: Scenario-Based Development of Human–Computer Interaction*, Morgan Kaufmann, 2002.
22. D. Kahneman, *Attention and Effort*, Prentice Hall, New Jersey, USA, 1973.
23. J. C. Bastien, Usability testing: some current practices and research questions, *The International Journal of Medical Informatics*, 2010.
24. D. Kahneman, *Attention and Effort*, Prentice Hall, New Jersey, USA, 1973.
25. W. Tavares and K.W. Eva, Exploring the impact of mental workload on rater-based assessments, *Advances in Health Sciences Education*, **18**(2), 2013, pp. 291–303.
26. S. G. Hart, NASA–Task Load Index (NASA–TLX); 20 years later, *Human Factor and Ergonomics Society Annual Meeting Proceedings*, General sessions, **50**(9), 2006, pp. 904–908.
27. Taiwan Special Education Transmit Net 2013. Special Edu-

cation Student Statistics, 2013, http://www.set.edu.tw/sta2/default.asp, accessed 15 July 2014
28. S. G. Hart and L. E. Staveland, Development of NASA–TLX (Task Load Index): results of empirical and theoretical research, *Human Mental Workload*, 52, **1**(3), 1998, pp. 139–183.
29. M. Mouzé-Amady, E. Raufaste, H. Prade and J. P. Meyer, Fuzzy-TLX: using fuzzy integrals for evaluating human mental workload with NASA–Task Load indeX in laboratory and field studies, *Ergonomics*, **56**(5), 2013, pp. 752–763.
30. C. M. Zhang, Ordinary high school students with visual impairments to adapt to school life and school support systems research, Changhua University of Education, Institute for Special Education Master's thesis, unpublished, Taiwan, 2002.
31. J. C. Nunnally and I. H. Bernstein, *Psychometric Theory*, 3rd edn, McGraw-Hill, New York, 1994.
32. G. Morgan, A word in your ear: library services for print disabled readers in the digital age, *Electronic Library*, **21**(3), 2003, pp. 234–239.
33. K. McNabb and M. Tamaira, Once upon a library: NVDA and the Aotearoa People's Network Kaharoa, in *Round Table On Information Access for People With Print Disabilities Conference*, Auckland, New Zealand, 2010, http://printdisability.files.wordpress.com/2010/11/8a-once-upon-a-library1.doc, accessed 15 July 2014.
34. S. Paterson, CNIB library for the blind: Placing library service for the blind in the community, 2011, http://www.collectionscanada.gc.ca/accessinfo/005003-3020-10-2001-e.html, accessed 15 July 2014
35. German Central Library for the Blind, Who we are and what we do, 2011, http://www.dzb.de/en/about-us.html, accessed 15 July 2014
36. D. Leahy and S. Lawler, NCBI and digital literacy: a case study, in *Computers Helping People with Special Needs*, Linz, Austria, 2012, pp. 243–250.

Appendix A: Questionnaire

Part I: Basic Information

1. Gender _______
2. Age__________
3. The degree of visual impairment_________________
4. Currently attending school and grades______________
5. Mathematic grades in the last semester________________

Part II: Questionnaire

The questionnaire was divided into the three parts, there were individual learning attitude, using assistive tools condition and mathematics learning environment. There were 34 questions in the questionnaire.

1. Individual Learning Attitude

Questions	Strongly disagree	Disagree	No opinion	Agree	Strongly agree
1. Because of visual impairments, I have frustration and distress in studying.					
2. Mathematics class and homework would give me a lot of pressure.					
3. I will read mathematics textbook voluntarily.					
4. I will preview the notebooks or notes before each mathematics class.					
5. I will well prepare for mathematics exam.					
6. I study the mathematics only because of an exam.					
7. I take notes in the mathematic course.					
8. I would not give up quickly when I meet difficulty in mathematics problems.					
9. I will organize the content of a mathematics textbook in an understandable way.					

Questions	Strongly disagree	Disagree	No opinion	Agree	Strongly agree
10. I take notes in the mathematic course.					
11. I would not give up quickly when I meet difficulties in mathematics problems.					
12. I will organize the content of a mathematics textbook in an understandable way.					
13. I won't be frustrated with bad mathematic grades.					
14. In order to get a better math score than others, I will try even harder to understand the content.					
15. I can understand the mathematical formula, coordinates and geometric problems easily.					
16. When I took a mathematic exam, I could answer each question with mathematical formulas and geometric coordinates easily.					
17. I will not be interested in the mathematics due to bad grades.					
18. I could distinguish the important and unimportant information in the lectures of the teacher.					
19. I prepared the mathematics exams temporarily.					
20. I can adapt myself to most of the lecture styles in mathematics courses.					
21. My parents had engaged a tutor to assist in my mathematics learning.					

2. Using the Assistive Tools Condition

Questions	Strongly disagree	Disagree	No opinion	Agree	Strongly agree
22. I used the screen reader software to assist in learning mathematics.					
23. The schools or teachers provided the assistive learning mathematics tools.					
24. Teachers have to teach how to install, use and configure the screen reader software.					
25. School has to provide the Braille materials (mathematics model and Braille textbooks) and assist students in using them.					
26. Schools should slightly modify commercially available assistive devices in order to meet the needs of students.					
27. The school has provided training or technical assistance in the use of assistive devices to family or primary caregiver.					
28. The teachers would make the assistive tools by themselves to increase the effectiveness of teaching.					
29. I will use special assistive tools to increase my learning performance.					
30. I think the mathematics teaching assistive tools school provided meet my needs.					
31. The special education teachers often provide resources and counseling services for me.					

3. Mathematics Learning Environment

Questions	Strongly disagree	Disagree	No opinion	Agree	Strongly agree
32. I have good interactions with the mathematics teacher.					
33. I would take the initiative for assistance from teachers and classmates when I encounter learning problems in the mathematics.					
34. The mathematics teachers would prepare the materials for students (such as the Braille, enlarged, drawing lines and increase the light).					
35. The instructor will encourage more class participations in various groups or individual learning activities.					
36. The teacher will provide the Braille materials.					
37. School has an additional unit to assist me in mathematic tutoring.					

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