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Enhancing Literacy for the Visually Impaired: The Role of eBraille Panels in Modern Education

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ABSTRACT

There is a problem of low literacy level amongst the visually impaired. Too many children are unexposed to Braille, and hence are not able to read or write. This causes some of the visually impaired to be missing out on a lot of knowledge that can be gained from reading. This project aims to create an eBook reader for the visually impaired by means of a refreshable Braille panel which enables them to read and gain more insight on certain subjects with more ease. The eBraille panel functions similarly for the visually impaired to how a monitor would for those who are sighted. They will touch the panel to feel the Braille codes that are displayed which are transferred from a data storage media in the form of a data stick. The data stick will store the digital form of the Braille book, and act as a Braille eBook. It also holds the corresponding audio of the contents of the book. This project provides the visually impaired with an audio assisted electronic Braille book reader.

Introduction

Background and Significance

As of 2021, the World Health Organization (WHO) estimates that approximately 2.2 billion people have a vision impairment or blindness, with at least 1 billion of these cases being preventable or yet to be addressed. According to the Malaysian Ministry of Health, there are around 36,000 registered visually impaired individuals in Malaysia as of 2020. These figures only account for those who are officially registered, and the actual number is likely higher. Braille was created to enable the visually impaired and blind to read, and since its inception, many written works have been translated into Braille.

Recently, the technology of eBooks has gained a lot of interest from readers of all ages. More and more people are publishing and reading eBooks, especially

with the accessibility and availability of eBooks, as well as the production of eReaders such as Kindle and Nook. Libraries worldwide are also beginning to open up to the idea of offering eBooks to their visitors. Among the benefits of eBooks for libraries are easy access to content due to on-demand availability, zero possibility of books getting lost, stolen, or damaged, the ability to search within a book, and no need for physical space. eBooks are accessible anywhere using any devices and even web browsers, and they are easily transported (Connaway, 2003). eBooks have an undeniable abundance of advantages that can be experienced by readers. However, there are those who do not get the opportunity to experience eBooks as easily as other people, such as the visually impaired.

Problem Statement

A major crisis in the visually impaired community is their literacy level. According to the American Printing House for the Blind (APH) 2021 Annual Report, only about 10% of blind children in the United States are learning Braille. Several factors contribute to the increasing number of illiterate visually impaired individuals (Spungin, 1989). Attitudes towards Braille have diminished, and potential Braille users often receive insufficient attention. Special education teachers may lack proficiency in Braille, complicating the education of visually impaired students. The complexity of Braille itself can be a barrier, leading many to rely on audio tapes and speech output devices. Additionally, there is a shortage of qualified Braille instructors.

Braille books present several issues: when regular books are translated into Braille, one moderately sized book turns into a few volumes of thick and heavy books, making them difficult to carry (Velázquez, Preza, & Hernández, 2008). Embossed paper tends to wear out after being read multiple times, rendering some Braille books unusable quickly. Additionally, Braille papers are expensive, sensitive, and difficult to store.

Braille readers feel that Braille provides them an outlet for independent reading and learning. It offers the opportunity to learn competitively with sighted learners and catch up with them, making them more comfortable and confident. Braille significantly impacts their work and daily activities, bringing about literacy for the visually impaired, which is threatened by the dependence on audio assistance. Braille is to the blind what print is to the sighted, and without Braille, many visually impaired individuals are at risk of illiteracy (Schroeder, 1994).

The creation of an electronic Braille panel can solve these issues, allowing the visually impaired to experience reading eBooks. This panel functions as a device for the visually impaired to read and appreciate reading using technology, just as sighted people do.

2.0 Existing Solutions and the eBraille System

Current Solutions and Challenges

The two most common methods in assisting the visually impaired in reading are screen readers and Braille displays. Both methods typically require the use of a computer as a medium.

Screen Readers: A screen reader is a text-to-speech software that reads aloud the text displayed on the computer screen for the visually impaired user. It acts as an interface between the computer's operating system, applications, and the user. By pressing different combinations of keys, the user can instruct the screen reader to perform various functions, such as reading or spelling a selected word, reading a line or a complete text, and identifying the cursor's position. Screen readers can also facilitate locating text displayed in a specific color, reading highlighted text, and providing spell checker functions for word

processors and screen reading for spreadsheets (American Foundation for the Blind, 2014). Screen readers are often used by individuals with partial vision and have been found to be useful for many visually impaired people who prefer listening to text rather than straining their eyes to read the screen.

Braille Displays: A refreshable Braille display is an electronic device that allows visually impaired users to read the text displayed on a computer monitor by touch. It is connected to the computer via USB and produces Braille characters using plastic or metal pins that move up and down to form the characters. This enables users to read the text through tactile feedback (American Foundation for the Blind, 2014).

BrailleNote: BrailleNote, a product by HumanWare, offers multiple functions for visually impaired users, including reading, writing, and listening to texts. It allows users to create, edit, and store documents, convert text into Braille and vice versa, and connect to printers and the internet via WiFi or Bluetooth. Users can share files, surf the internet, download emails, and connect to a wireless QWERTY keyboard. BrailleNote also features an enhanced media player, microphone for voice recordings, email functionality, a daily planner, and an address list. Users can read eBooks in text converted into Braille or directly in Braille, with the option to choose the grade of Braille they prefer. Additional features include a stopwatch, scientific calculator, and a visual display for sighted individuals (HumanWare, 2014).

While these devices have significantly improved accessibility for the visually impaired, they come with several challenges. Screen readers, although effective, require a steep learning curve and constant updates to keep up with new software versions. Refreshable Braille displays are expensive and can be cumbersome to carry around. Additionally, they only display one line of Braille at a time, which can be limiting for extended reading. Devices like BrailleNote offer a wide range of functionalities but can also be costly and require technical expertise to use effectively.

Introduction to the eBraille System

The eBraille system is an innovative solution designed to address the limitations of traditional Braille books and modern electronic Braille displays. This system aims to provide a more portable, efficient, and user-friendly means of reading for the visually impaired, combining the tactile benefits of Braille with the convenience and versatility of digital technology.

Features and Benefits

Portability and Convenience: The eBraille panel is designed to be lightweight and portable, allowing users to carry it easily wherever they go. Unlike traditional Braille books, which can be bulky and heavy, the eBraille panel offers a compact solution that can store thousands of pages of Braille text digitally.

Enhanced Reading Experience: The eBraille panel features refreshable Braille cells that allow users to read text line by line, similar to traditional Braille displays. However, it also incorporates advanced features such as adjustable reading speeds, customizable Braille grade settings, and integrated audio feedback to enhance the reading experience.

Connectivity and Integration: The eBraille system can connect to various devices, including computers, tablets, and smartphones, via USB and wireless connections. This allows users to access a wide range of digital content, including eBooks, emails, and online articles, directly on their eBraille panel. The system also supports file sharing and synchronization with cloud storage services, ensuring users

have access to their documents anytime, anywhere.

Long Battery Life: With an efficient power management system, the eBraille panel offers extended battery life, allowing users to read for hours without needing to recharge. This is particularly beneficial for users who are on the go and may not have easy access to power outlets.

User-Friendly Interface: The eBraille panel is designed with an intuitive interface that makes it easy for users of all ages and technical abilities to navigate and operate. The system includes tactile buttons, voice commands, and a simple menu structure, ensuring a seamless and accessible user experience.

Educational and Professional Applications: The eBraille system is not only useful for personal reading but also has significant applications in education and professional settings. It enables visually impaired students to access textbooks, academic papers, and other educational materials in Braille, facilitating inclusive learning. In professional environments, the eBraille panel allows users to read and write documents, manage emails, and perform other work-related tasks efficiently.

By addressing the limitations of existing solutions and leveraging modern technology, the eBraille system offers a comprehensive and effective tool for enhancing literacy and accessibility for the visually impaired.

3.0 The eBraille System Design and Development

Panel Structure and Components

Books printed in Braille are very thick and some have to be separated into volumes. For example, a printed 2nd Edition Merriam-Webster dictionary, which is around 15 cm thick, is embossed into 32 volumes with a thickness of 30 cm each. This would amount to a hefty weight of numerous kilograms for the visually impaired to carry around. Not only is there a problem with mobility, but there is also an obvious problem of keeping track of the volumes, pages, and indexes. Furthermore, the dots on the embossed book may wear out if touched frequently, and characters will eventually be difficult to recognize (Razaly et al., 2010). There is also a problem with the storage of Braille books.

The eBraille panel is designed to be both functional and portable, addressing these challenges. The panel measures 340 mm in length, 140 mm in width, and 50 mm in height at its maximum point, with a weight of 1.14 kg. The primary components include:

- **Dimensions**: 340 mm (length), 140 mm (width), 50 mm (maximum height), 34 mm (minimum height), and 2 mm (thickness).
- **Weight**: 1.14 kg.
- **Keys and Controls**: The panel is equipped with various keys including escape, enter, spacebar, backspace, next, back, and audio control keys to facilitate user interaction.
- **Connectivity**: Features USB and wireless connectivity options allowing it to interface with computers and other devices for data transfer and control.

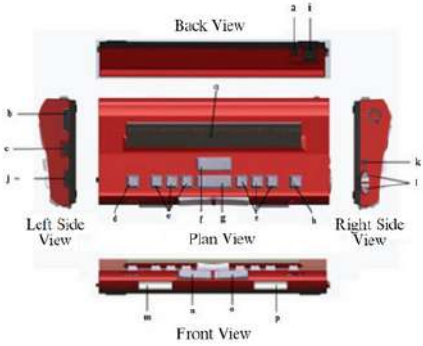

Figure 1 : Overview of the eBraille Panel with labels for dimensions and key components.

Table 1. Overview of eBraille Components

Label	Name
a	Power adapter socket
b	Data Stick slot
c	Universal Serial Bus (USB) socket
d	Escape key
e	Perkin key
f	Enter key
g	Space key
h	Backspace key
i	Main switch
j	Wireless switch
k	Audio socket
l	Audio adjustment key
m	Play / Pause key
n	Back key
o	Next key
p	Stop key
q	Braille cell

Braille Cells and Configuration

The eBraille panel contains 40 Braille cells, each with eight dots driven by piezo-actuators, enabling dynamic Braille character display. The configuration allows for the representation of various Braille codes and provides a tactile reading experience for visually impaired users. The Braille cells are arranged in a single line, and each cell's pins move up and down to form Braille characters that can be read by touch. This system supports both six-dot and eight-dot Braille configurations, catering to different user needs.

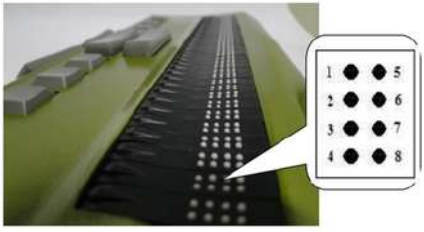

Figure 2: Detailed view of Braille cells and their configuration.

Power Supply and Interface

The power supply and interface components are crucial for the panel's operation and user interaction:

- **Power Supply**: The panel operates on a lithium-ion battery (8.4V, 2040mAH) or an external 12V DC adapter. The battery life is approximately three hours in standalone mode.
- **Interface**: The panel includes a 3.5 mm audio jack, mono audio output, and both USB and wireless communication capabilities. The wireless switch can activate or deactivate the wireless function, allowing for flexible connectivity options.
- **Audio System**: Integrated audio functionality supports adjustable volume and provides audio feedback to assist beginners in learning Braille. The audio system can be connected to earphones or headphones via a standard 3.5mm audio jack.

Figure 3: Diagram of power supply connections and interface ports.

Data Stick and Storage

The electronic Braille Panel has been developed for the main objective of representing the printed Braille reading materials. An innovative device, this electronic panel can hold and display any form of reading material subjected to it. A line of raised dots representing a line of the Braille reading material will appear at the top of the panel for the visually impaired to feel and read. This effect is produced by the automated upward and downward movements of the pins in the Braille cells. This technology provides a user-friendly, effective, and efficient medium for the visually impaired to read and appreciate any reading materials without the many setbacks they currently face. This device is much lighter compared to the current printed editions of most Braille books, as most of them come in multiple volumes. Hence, visually impaired users will find it easy to carry the panel around, and access more than one of their reading materials anytime, anywhere.

The data stick is a key component of the eBraille system, designed to store Braille data in a secure and accessible format:

- **Data Stick Design**: The data stick resembles an SD card, making it compact and easy to handle. It is designed specifically for the eBraille panel and features encrypted data to protect intellectual property.
- **Storage Capacity**: The current capacity of the data sticks is 2GB, which can store a large number of eBooks. There is ongoing development for an 8GB data stick to accommodate even more content.
- **Functionality**: The data stick operates in a 'plug and play' manner. Once inserted into the panel, it retrieves encrypted Braille text data, decrypts it into Braille code, and displays it on the panel's Braille cells. This allows users to access and read a wide range of texts easily. The data stick also includes audio files,
- Enabling users to listen to text while reading, which is particularly useful for beginners.

Figure 4: Illustration of the data stick and its insertion process into the eBraille panel

4.0 Implementation, Results, and Discussion

Implementation Process

The implementation of the eBraille system involved a comprehensive and structured approach to ensure its effectiveness and usability for the visually impaired community. The process can be broken down into several key phases:

1. Initial Development and Prototyping:

The eBraille panel was initially developed and prototyped, focusing on integrating key components such as Braille cells, audio systems, and connectivity options. The design aimed to be user-friendly and efficient, providing a portable and durable solution for Braille literacy.

2. Classroom Testing:

- To evaluate the functionality and effectiveness of the eBraille system, classroom testing sessions were conducted in collaboration with the the Malaysian Muslim Visually Impaired Society (PERTIS). These sessions were held at The Legend Hotel Kuala Lumpur for the central zone and Primula Beach Hotel Kuala Terengganu for the eastern zone.

- A total of 65 respondents participated, with 41 from the central zone and 24 from the eastern zone. The participants included both visually impaired individuals and those without visual impairments, providing diverse feedback.

3. Feedback Collection:

- Participants provided feedback through structured questionnaires containing 41 questions, covering aspects such as general design, audio system, keys, external design, wireless functionality, and data display. Each aspect was rated on a scale from 0 to 4, helping identify areas for improvement and key strengths.

4. Refinement and Enhancement:

- Based on the feedback, several enhancements were made to the eBraille panel. Suggestions included making the 'Next' and 'Back' keys smaller and arranging them more systematically, adding tactile symbols on keys for new users, and improving the spacing of Braille dots for beginners. These refinements were incorporated to improve the overall user experience.

5. Final Testing and Deployment:

- After incorporating the suggested improvements, the eBraille panel underwent final testing to ensure all enhancements were effectively implemented. Once validated, the system was prepared for broader deployment.

Results and Discussion

The results from the classroom testing sessions provide valuable insights into the effectiveness and user satisfaction of the eBraille panel.

Quantitative Analysis of Feedback:

The feedback from the 65 respondents was quantified and analyzed to assess the various aspects of the eBraille panel. Table 2 presents the scale used to measure the level of agreement from respondents regarding various aspects of the eBraille panel. Each aspect was rated on a scale from 0 to 4.

Table 2 Measurement Scale for User Satisfaction Questionnaire.

Level of Agreement to Questions	Score	Details
Not Applicable	0	This rating was given when respondents felt that a particular question or aspect did not apply to their experience or usage of the eBraille panel.
Strongly Disagree	1	Respondents selected this rating when they strongly disagreed with the statement or aspect being evaluated, indicating a significant issue or dissatisfaction.
Disagree	2	This rating reflects respondents' disagreement with the statement or aspect, showing that they were not satisfied, though the issue might not be as severe as indicated by a score of 1.
Agree	3	This rating was chosen by respondents who agreed with the statement or aspect, indicating general satisfaction with the feature or function being evaluated.
Strongly Agree	4	The highest rating, selected by respondents who were highly satisfied with the particular aspect of the eBraille panel, reflecting strong positive feedback.

The average ratings for each evaluated aspect, on a scale from 0 to 4 are shown in Table 3.

Table 3: Summary of Feedback on eBraille Panel Design and Usability.

Aspect	Average Rating	Discussion	Recommendation
General Design	3.7	Users found the panel well-constructed and aesthetically pleasing. Its portability and lightweight design were appreciated.	
Audio System	3.5	Received positive feedback for clarity and usefulness, especially for beginners learning Braille.	Users suggested further enhancements in volume control and audio quality.
Keys	3.4	Generally well-received.	Users recommended making the 'Next' and 'Back' keys smaller and arranging them more systematically. Tactile symbols on keys were also suggested to aid new users.
External Design	3.6	Praised for durability and ergonomic structure, comfortable for extended use.	
Wireless Functionality	3.3	Users appreciated the wireless functionality, which allowed for flexible connectivity.	Need for more reliable wireless connections and longer battery life
Data Display	3.8	The data display was highly rated, with users finding the Braille cell configuration effective for reading various Braille codes.	Improvements are need for spacing of Braille dots to better accommodate beginners.

The comprehensive testing and feedback process has demonstrated that the eBraille panel is an effective tool for enhancing Braille literacy among the visually impaired. The positive feedback highlights the panel's potential to significantly impact the visually impaired community by providing a portable, efficient, and user-friendly reading solution. Further refinements based on user suggestions will continue to improve the system, ensuring it meets the diverse needs of its users.

Impact on the Visually Impaired Community

The implementation of the eBraille system has had a significant positive impact on the visually impaired community, addressing several longstanding challenges associated with Braille literacy. The eBraille panel provides an accessible solution for visually impaired individuals to read and write Braille, overcoming the physical limitations of traditional Braille books. Its portable design allows users to carry and access multiple reading materials anytime, anywhere.
The integration of audio feedback and customizable Braille display settings enhances the learning experience for beginners and advanced users alike. The ability to bookmark, adjust reading speeds, and choose different Braille grades caters to users with varying levels of proficiency.

The eBraille system supports inclusive education by enabling visually impaired students to access textbooks, academic papers, and other educational materials in Braille. In professional settings, the system allows users to read and write documents, manage emails, and perform other work-related tasks efficiently.

By providing a user-friendly and efficient medium for reading, the eBraille panel empowers visually impaired individuals, enhancing their independence and confidence. It enables them to engage with written content more effectively, bridging the gap between sighted and visually impaired learners.

The comprehensive testing and feedback process has shown that the eBraille panel is well received by the visually impaired community. Users have reported high satisfaction with its portability, ease of use, and the efficiency of its Braille display and audio system.

5.0 Conclusion

Braille acts as a gateway for literacy to the visually impaired, especially those who cannot even manage to read large print. Braille might be viewed as irrelevant to some, but to others, it is seen as have "liberated a whole class of people from a condition of illiteracy and dependency and has given them the means for self-fulfilment and enrichment" (Nemeth, 1988). For some visually impaired adults, “Braille represents competence, independence and equality” (Schroeder, 1994). For them, mastering and using Braille plays a dominant role in the development of self-identity of a visually impaired person. "Braille makes it possible for a blind person to assume a role of equality in modern society, and it can unlock the potential within him (sic) to become a contributing member of his community on a par with his sighted fellows" (Nemeth, 1988).

An efficient reading medium, or set of mediums facilitates literacy and integration into social, learning, and work environment and provides individuals with a recreational skill that cannot be replaced with television, radio, or other media” (Wormsley & D'Andrea, 1997). Audio assistive devices can never take the place of Braille, as it does not provide the same benefits that reading Braille does. The American Council of the Blind stated that recorded materials are mere complements, and not substitutes for Braille. In 1983, the National Library Service for the Blind and Physically Handicapped

(NLS) published the findings of a Braille Reader survey (National Library Service for the Blind and Physically Handicapped, 1983). This survey revealed that a majority of the Braille readers preferred Braille as their primary reading medium, signifying that Braille was an important part of the lives of visually impaired Braille readers. The findings also indicated that Braille readers borrowed fewer books not due to dissatisfaction with the medium of Braille, rather they were dissatisfied with the collection of books available in Braille. Therefore, making eBooks available to the visually impaired through the eBraille panel would solve so many of the issues affecting the visually impaired community.

The use of technology is advantageous to the visually impaired. This project allows the visually impaired to be able to read Braille books easily through eBooks projected on an eBraille panel. A research report found that “a range of technology, which includes Braille, offers the visually impaired more flexibility” (Douglas, Franks, Weston, & Clements, 2009). The eBraille panel and data stick allow the visually impaired to be as updated with the latest technology trend as sighted people. By providing means for the visually impaired to read Braille eBooks, Braille may not be as obsolete as some claim it to be.

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