TECHNOLOGIES AND APPROACHES IN BRAILLE EDUCATION: A SYSTEMATIC LITERATURE REVIEW

Azizah Awang[1], Intan Farahana Abdul Rani[2*], Kway Eng Hock[3], Mohd Yahya Fadzli Jusoh[4], Siti Nordarma Ab Rahman[5]

[1] Faculty of Human Development, Universiti Pendidikan Sultan Idris, Malaysia
     Email: aziey2143@gmail.com
[2] Faculty of Human Development, Universiti Pendidikan Sultan Idris, Malaysia
     Email: intanfarahana@fpm.upsi.edu.my
[3] Faculty of Human Development, Universiti Pendidikan Sultan Idris, Malaysia
     Email: kway.eh@fpm.upsi.edu.my
[4] School of Educational Studies, Universiti Sains Malaysia
     Email: fadmy29@gmail.com
[5] School of Educational Studies, Universiti Sains Malaysia
     Email: sitinordarma@gmail.com
*   Corresponding Author

Article Info:

Abstract:

Braille education is an important tool for people with visual impairments to help them read and write and provide more educational opportunities. Despite the important role of braille in the education and freedom of individuals with visual disabilities, they face many barriers to access and learning, including a lack of trained teachers, inadequate technological resources, and limited integration of braille in mainstream education curricula. The objective of this article is to conduct a systematic literature review (SLR) on technologies and approaches in braille education. This systematic review involved six articles reviewed in the PRISMA framework, which involved the selection process of articles filtered through four stages such as identification, screening, eligibility, and articles meeting the final criteria (included). Scopus and Web of Science databases from 2014 to 2024 were used in the study and assisted with Mendeley software. As a result, two themes were selected: technology and approaches in braille education. This study suggests future research evaluating the effectiveness of different approaches in different cultural and economic contexts to produce more comprehensive guidance.

Keywords:

Braille Reading, Raised-Dot Reading, Tactile Literacy, Tactile Reading, Touch Reading

Introduction

Technological advancements in recent years have completely transformed the field of braille education, providing unparalleled accessibility and chances for interaction (Hoskin et al., 2024). The digital era has seen the rise of different technology aids that can be used to bridge traditional teaching, and these aids include electronic braille displays and interactive programs, among other forms of online technologies (Shalini et al., 2020). This essentially revolutionized the training of braille learners with new approaches to instruction that were interactive and adaptable to individual needs (Tisnawati, Yuliati & Purbaningrum 2022). Moreover, the availability of braille education on a large scale with these technologies is contributing to overcoming barriers and enabling individuals across the globe who have vision impairment to realize their educational goals.

However, there are some key issues that need attention in braille education. One of the important issues is access to technology. Although braille technology has developed rapidly, access to these aids remains uneven, especially in rural and low-income areas (Hoskin, Pinder & Davies 2024). This lack of access can hinder effective teaching and learning of braille, contributing to inequalities in education.

In addition, teacher training and professional development are critical issues. There is a constant need for professional development for teachers so that they are constantly updated with the latest braille teaching methods and technologies (Parween & Dheesha, 2018). Without adequate training, the quality of teaching can be affected and the potential benefits of new technologies in braille education may not be fully exploited.

Curriculum integration is also a significant challenge. Integrating braille education into the standard curriculum can be difficult due to a lack of resources and expertise (Croake, Gentle & Duncan 2024). This can lead to students not receiving a comprehensive braille education, which in turn affects their overall academic performance and literacy.

Furthermore, cognitive and neurological considerations in braille learning are still in the developmental stage. Understanding the cognitive and neurological processes involved in braille learning is essential to improving teaching methods as well as supporting students cognitive development (Martiniello & Wittich, 2022). Without this knowledge, teaching methods may not fully meet the unique learning needs of visually impaired students.

Finally, standardization and quality control in braille teaching are issues of concern. There is a lack of standardized teaching methods and learning materials in braille education (Kana & Hagos, 2024). Variations in teaching quality can lead to inconsistent learning outcomes for students. Figure 1 shows the issues faced in braille education.
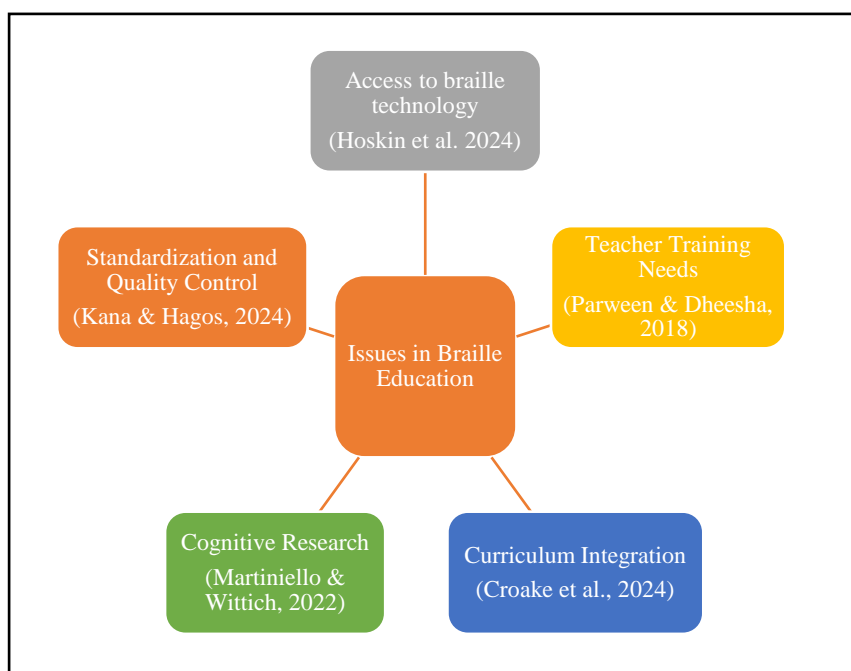
Figure 1: The Issues Faced in Braille Education

To address issues faced in braille education, effective pedagogy is one of the key factors for braille education includes instructional practices and learning results (Alya Qasdina Ng Ai Lee & Kway, 2023). The subject states the importance of lifelong learning for educators in braille instruction (Croake, Gentle & Duncan 2024). They need updated ways of teaching braille using multimodal practices and differentiated instruction to meet the diverse learning needs of their students (Geel et al., 2023). It is also of vital importance that teachers continue to learn so as to enhance their standards and competence in teaching, which undoubtedly would positively affect students' achievements; thus, resources placed for teacher professional development will ensure greater educational guidance where the changing nature of school instructions can be met.

Understanding the cognitive and neurological mechanisms linked to using braille is central to improving teaching methods, as well as supporting learners' cognitive development (Martiniello & Wittich, 2022). The focus of this topic is on the cognitive bases of braille education - how people perceive, process, and understand braille information (Croake, Gentle & Duncan 2024). Research in cognitive neuroscience and psychology is what tells us about the different cognitive processes involved in braille reading and writing (Amoah 2022; Englebretson, Holbrook & Simon 2023). Furthermore, knowledge gained on the neural mechanisms that support braille reading could alleviate future treatments and training protocols aiming to increase braille education among visually impaired individuals (Hoskin et al., 2024). By utilising on these important insights, the availability as well efficiency in promoting cognitive development and academic success will be ensured through braille instruction.

This systematic literature review aims to recognize and examine the braille education approach used in different educational settings, together with assessing their efficiency in student learning consequences. Next, we delve into what is being done to innovate braille education and improve its educational outcomes through technology. In the context of this study, the objective to be achieved by the researcher is to identify the technologies and approaches used

in braille literacy education. The review covers topics that include research, literature review, methodology, results and findings, discussion and conclusions. Figure 2 shows the article outline.
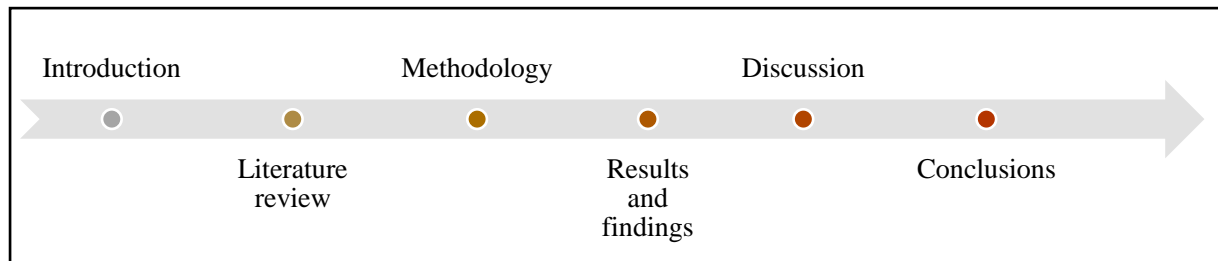
Figure 2: Article Outline

Literature Review

Reading and writing in braille are key skills that, for those with visual impairments, have been essential to the ability to become part of mainstream education and society. Yet, the efficacy of braille teaching methods is an ongoing topic with significant controversy (Croake, Gentle & Duncan 2024). The utilization of multisensory techniques based on the Multisensory Learning Theory, which involve the integration of auditory, tactile, and kinesthetic modalities, is intended to increase conceptual understanding by having two or more systems work together at the same time (Alwashmi et al., 2024). Supporters will argue that this leads to a far more well-rounded learning experience and, crucially, centers on the acquisition of literacy skills (Mondesir & Griffin 2020). Structured literacy principles groups, such as those supported by the International Dyslexia Association, are organized to handle linguistic concepts: phonology, morphology, and semantics based on Structured Literacy Approach.

Some advocates of braille observers are recommending systematic literacy techniques as a promising approach to improving reading fluency and comprehension in systematic literacy approaches. These methods provide a structured approach to establishing the abilities that are desired (Mondesir & Griffin, 2020). The use of technology has also seen profound changes in braille education. It has brought in interactive learning devices and a whole lot of braille study materials. Virtual media delivers tailored learning experiences that suit the diverse needs and preferred styles of learners (Bhat, 2023). Furthermore, the implementation of Universal Design for Learning (UDL) ensures equitable and inclusive braille education by responding to the wide range of learning styles & potencies among students (Hasan, Khan & Malik 2023).. With the aid of UDL principles, educators can customize instruction and materials to meet all learners' varied needs, restoring an inclusive learning environment.

The impacts of braille instruction are wide-ranging and extend beyond academic areas to impact various aspects of individuals' lives (Hoskin et al., 2024). According to Croake, Gentle and Duncan (2024) mastery of braille reading and writing to a high level will enhance all levels of the academic process, resulting in lifelong learning tendencies. Early braille instruction is positively related to increased braille literacy skill development for individuals who are blind (Alya Qasdina Ng Ai Lee & Kway, 2023). This underscores how intervention is good when timely and effective teaching methods are part of it. In addition, braille proficiency offers individuals abundant educational and vocational options that allow them to continue their education beyond high school, hold good-paying jobs, and live independently (Martiniello & Wittich, 2022). Learning how to read and write in braille enables learners not only with the

most fundamental skills but also in stills confidence for intellectual independence: a belief in one's abilities alongside self-assurance and decision-making (Susanti & Rudiyati, 2019). Braille proficiency enables individuals to successfully self-advocate for their educational rights, actively participate in society, and thereby have the ability to reach personal and professional goals (Croake, Gentle & Duncan 2024). Inclusive education, autonomy, equity, and equal opportunities for the visually impaired population are thus synonyms of a society with the prospect of being more equitable and inclusive.

To summarize, effective methods of braille instruction are critical for promoting the power and authority blind people from reading braille. Using multisensory methods, structured literacy methodologies, technology integration, and UDL principles allows braille learners to learn information in different ways based on their individual needs and preferences. By investing in a full braille education, educators, policymakers, and other stakeholders are fostering educational achievement for students who have visual disabilities, which would help promote equity and inclusivity in education.

Methodology

This systematic literature review uses a qualitative approach. Qualitative research questions are more flexible, adaptable, and not limited to specific areas or subcategories (Creswell, 2013). Sub-questions can help solve problems and clarify content to explore processes and experiences. Mantzoukas (2008) states that researchers need to examine the content of their research, the relationship with the theory, and its structure. The questions used are adapted by the study Hong et al., (2018). Systematic reviews entail a meticulous and all-encompassing pre-planned search method aimed at minimizing bias by discovering, evaluating, and combining pertinent studies on the subject (Haase, 2011). We conducted a comprehensive analysis of previously reviewed articles, providing a detailed account of the study's characteristics and significant discoveries. Furthermore, we assessed the quality of the research and deliberated potential explanations for the findings. In order to achieve a thorough search, this chapter employed methical searching tactics. Three sub-processes included in systematic searching techniques were conducted, including identification, screening, and eligibility assessment. Figure 3 shows the steps taken for the systematic literature review.
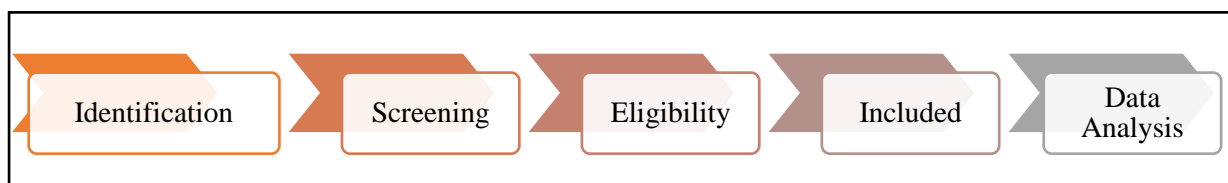
Figure 3: Step for the Systematic Literature Review
Source: (Mohamed Shaffril et al., 2021)

Identification

The systematic review process employed three fundamental phases to choose several pertinent papers for this investigation. In the initial stage, one must identify keywords and search for relevant terms utilizing resources such as online thesaurus, keywords suggested by Scopus, keywords suggested by experts, and previous research. Once all the phrases have been selected, we can draw up search strings for the Scopus and Web of Science databases (see Table 1). The first step of the systematic review process retrieved a total of 89 papers from both databases in this study project. All the papers and documents went on to the second step, which was screening.

Table 1: Full Search String Used in Selected Database (Scopus and Web of Science)

Scopus	TITLE-ABS-KEY (((("tactile reading" OR "touch reading") OR "braille literacy") AND (proficiency OR skills)))
Web of Science	((("tactile reading" OR "touch reading") OR "braille literacy") AND (proficiency OR skills)) (Topic)

Screening

Duplicate papers should be discarded in the first round of screening. In the first stage, 68 papers were excluded based on different inclusion-and-exclusion criteria outlined by the researchers; in the second phase, no articles were analyzed. It was the first criterion since literature or research articles, is the primary source of knowledge that is beneficial. Furthermore, the current study does not comprise book series or books published as papers and chapters in a review, meta-analysis of multiple studies and systematic reviews on literature research, which excludes all types of conference proceedings. Furthermore, the review was limited to English-language publications. It is crucial to keep in mind that the plan was set for a period from 2014 until 2024. Total publications of 21 according to preset standards.

This study does not involve the latest studies because the topics written still prevail in less mature fields. According to Kraus, Breier and Dasi-Rodriguez (2020), in less mature fields, the number of articles available is limited and more scattered because there are still many unanswered considerations. Currently, this SLR can form in shaping new theories based on existing articles (Linnenluecke, Marrone & Singh, 2020). In addition, the purpose of looking for SLRs in this immature field is to meet the lack of data and encourage researchers to conduct empirical studies in the future (Petticrew & Roberts, 2006). Table 2 shows the selection criterion is searching.

Table 2: The Selection Criterion is Searching

| Criterion	Inclusion	Exclusion
Language	English	Non-English
Timeline / Years	2014 – 2024	Before 2014
Document Type	Journal (Article)	Conference, Book, Review
Publication stage	Final	Article in Press

Eligibility

There are 17 articles ready for the eligibility phase, which is the third step. At this point, the titles and critical content of every article were carefully examined to make sure that they were relevant according to the inclusion criteria regarding the current study and its goals. For the purpose of ensuring the quality of the selection of articles to be included, two panels consisting of lecturers in the field of special education evaluated the articles based on the research objectives, population and fields associated in this study. As a result, 11 reports were removed:

due out of field (n=8), and the abstract did not link to it based on empirical data (n=3). Figure 4 shows flowchart of included articles retrieval process.

Data Abstraction and Analysis
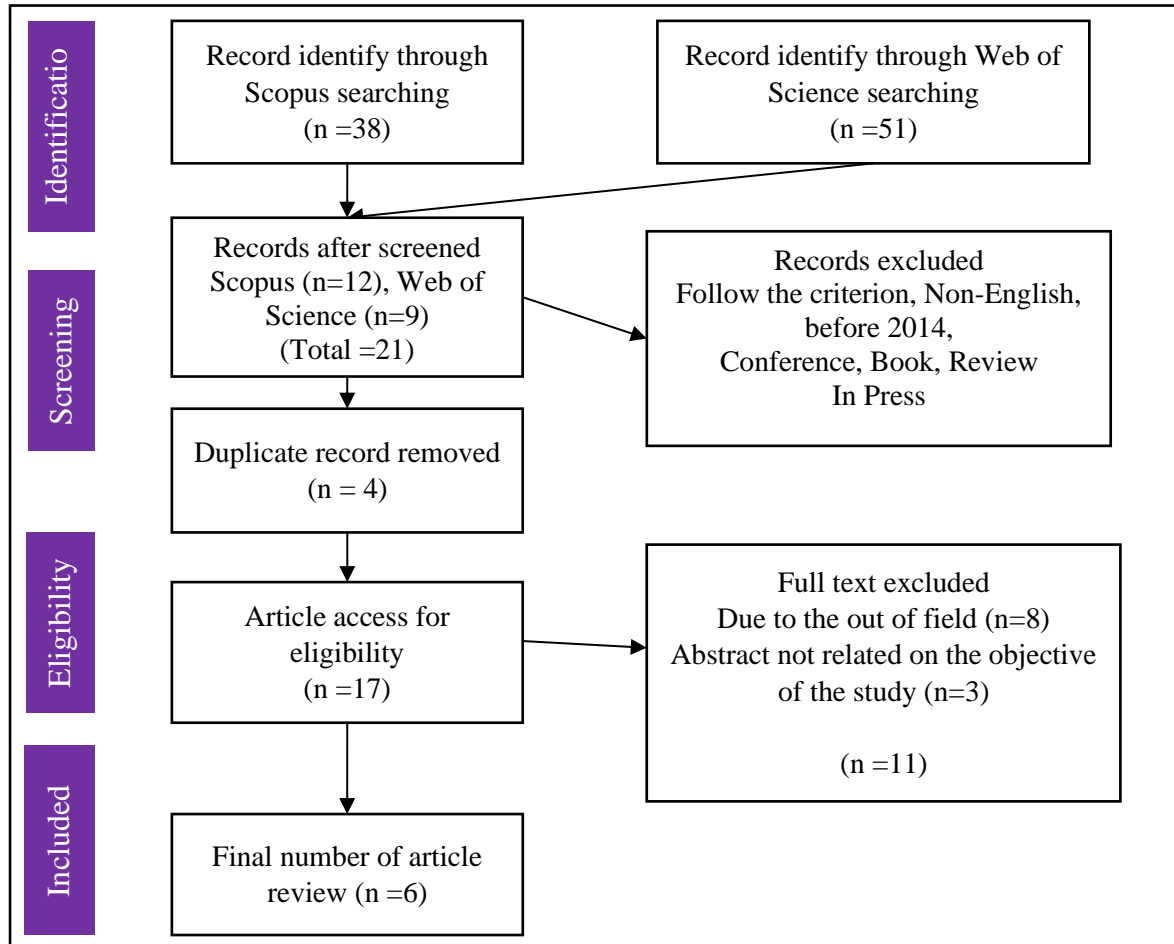
Figure 4: Flowchart of Included Articles Retrieval Process

In conclusion, the document's PRISMA flow diagram describes how to find, evaluate, and choose studies for a systematic review. At first, 38 records were obtained from Scopus and 51 records were obtained from Web of Science. After the screening process, any duplicate records were eliminated, leaving a total of 21 records for further examination. Out of these, 12 were sourced from Scopus and 9 from Web of Science. A total of 68 records were removed based on specified criteria, such as non-English publications, publications before 2014, conference papers, book reviews, and works that were still awaiting publication. After the screening, full-text articles were reviewed to determine if they fell within predetermined inclusion criteria. Two whole papers were omitted, and eight paper was entirely excluded due to a lack of relevance to the research question and three papers abstract did not clearly concern our study aim. Finally, six articles met all the inclusion criteria and were included in this review. Table 3 shows a summary including six research articles reviewed.

## Table 3: A Summary Including Six Research Articles Reviewed

Study	Analysis of Data	Participants	Themes	Findings	Challenges of Data Management	Distribution and Collection
McCarthy et al., (2016)	Mix-Method single-subject, teacher interviews, and surveys	10 students 7 teachers	Technology in braille education	Braille Tutor showed promise in supplementing braille instruction, potentially leading to faster learning and better outcomes.	Ensuring consistent and accurate reinforcement through AI.	Data collected through student interactions with the AI tutor and qualitative interviews and surveys with teachers.
Hoskin et al., (2024)	Qualitative	25 students	Technology in braille education	BrailleBunny prototype is promising but needs improvement in affordability, durability, and reliability.	Financial accessibility, durability, and reliability of the prototype.	Data collected through iterative design process involving end-user feedback.
Kamei-Hannan (2023)	Qualitative	44 teachers 48 Students	Technology in braille education	The app showed positive results for braille literacy, but teacher support is necessary.	Requires extensive professional and technical support.	Data collected through teacher and student involvement, and extensive professional development sessions.
Bola et al., (2016)	Quantitative	29 sighted adults (braille teachers and educators)	Approach in braille education	Sighted adults can learn braille reading with proper training.	Ensuring adequate motivation and correct methods for sighted adults learning braille.	Data collected through a nine-month braille reading course.

Study	Analysis of Data	Participants	Themes	Findings	Challenges of Data Management	Distribution and Collection
Herzberg et al., (2017)	Quantitative	84 teachers	Approach in braille education	Braille is introduced at various ages based on student needs. Motivation is crucial for successful braille use.	Variability in instruction time and methods, need for a comprehensive curriculum.	Data collected through an online survey of teachers
Herzberg et al., (2023)	Quantitative	17 teachers	Approach in braille education	Teachers' knowledge and skills improved, but challenges remain in applying Nemeth Code.	Common errors in formatting and symbol usage indicate ongoing need for professional development.	Data collected through pre- and post-tests, and assignment submissions.

Result and Finding

Braille literacy education is especially important for visually impaired individuals, allowing them to reach a level of reading and writing ability equivalent to their peers. Various technologies and approaches have been introduced to improve the effectiveness of braille education. The articles analyzed can be categorized into two main themes: the use of technologies and approaches in braille education. These articles provide in-depth insights into ways to improve braille teaching and learning. Figure 5 shows the themes and sub-themes in braille education.
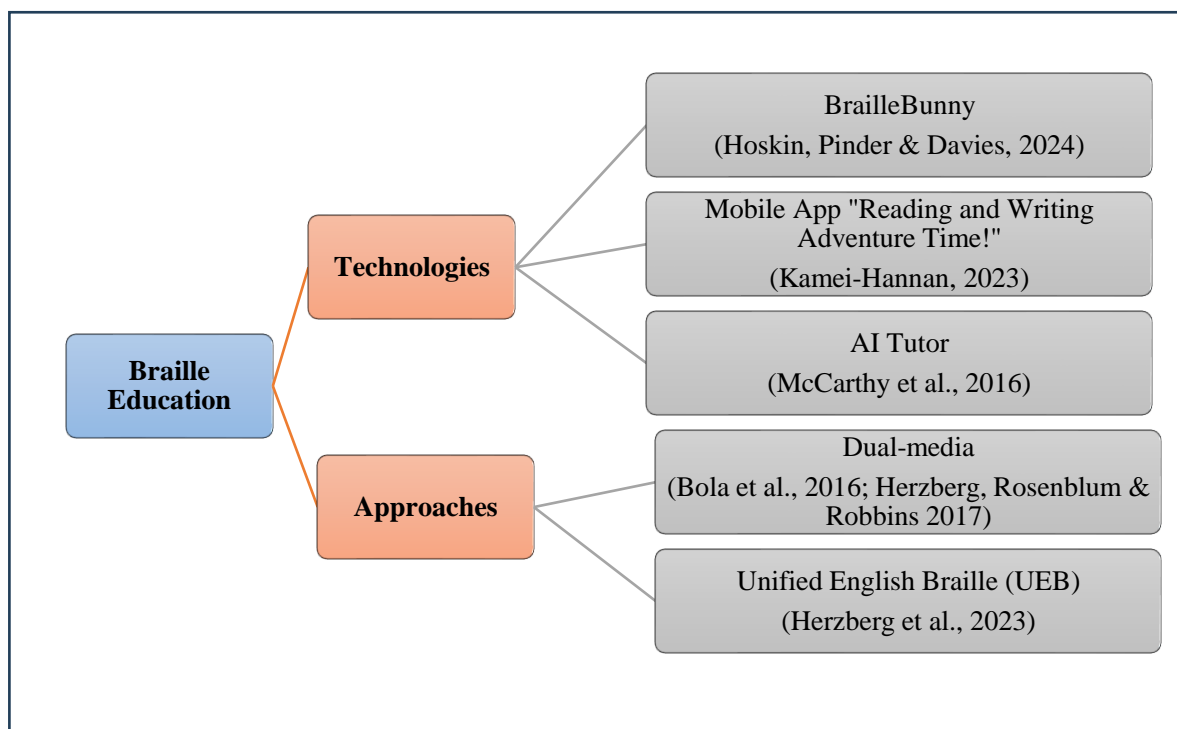
Figure 6: Theme And Sub-Themes For Braille Education

Theme 1: Technology in Braille Education

Several studies have shown the importance of technology in braille education. First, a study on the development of BrailleBunny by Hoskin, Pinder and Davies (2024) demonstrating that these tools, while still requiring improvements in financial capability, robustness, and reliability, have the potential to improve braille learning. User feedback suggests that BrailleBunny can provide transferable learning to standard-sized braille, especially in areas with high rates of braille illiteracy such as the Philippines.

In addition, an article by Kamei-Hannan (2023) about the mobile app "Reading and Writing Adventure Time!" also shows that technology can play an important role in braille literacy. The application, designed with the involvement of teachers and students, received high ratings for reading and writing ability, with extensive professional and technical support provided throughout its implementation.

A study by McCarthy et al. (2016) about the use of braille tutors based on artificial intelligence (AI) also shows the effectiveness of technology in braille education. Students using AI tutors achieve 100% faster accuracy and learn more braille contractions compared to traditional

methods. These AI tutors provide more frequent and consistent reinforcement, which increases student motivation in braille learning.

Recent studies show the importance of technology in braille education. The development of BrailleBunny by Hoskin, Pinder and Davies (2024) suggests that this tool, while still in need of improvement, has the potential to improve braille learning, especially in areas with high rates of braille illiteracy such as the Philippines. Article by Kamei-Hannan (2023) about the mobile application "Reading and Writing Adventure Time!" also shows that technology can play an important role in braille literacy, with high ratings for reading and writing ability as well as extensive professional support. A study by McCarthy et al. (2016) on the use of braille tutors based on artificial intelligence (AI) demonstrated the effectiveness of technology in braille education, with students achieving accuracy faster and learning more braille contractions compared to traditional methods, as well as increasing learning motivation.

Theme 2: Approaches in Braille Education
In this theme, the study emphasizes the approaches used in braille education and their importance. Bola et al. (2016) conducted a study of 29 literate adults who took a braille reading course for nine months. The study found that most participants were able to read full words in braille at an average speed of six words per minute. This study shows that literate adults can learn to read braille with the right method and high motivation.

Herzberg et al. (2023) examine the impact of concurrent professional development on the knowledge and skills of 17 Nemeth code teachers in the context of Unified English Braille (UEB). The results showed an improvement in post-practice exam scores, however, none of the participants submitted the final work without errors. This demonstrates the continuing need for professional development and additional resources to build teachers ' skills in the Nemeth code.

Additionally, a study by Herzberg, Rosenblum, and Robbins (2017) that analyzed the experiences of 84 teachers in literacy instruction to dual-media students using print and braille, showed that student motivation and confidence are important factors in determining whether students should switch from print to braille. The study also shows that a comprehensive curriculum is required for print readers who switch to braille.

The studies in this theme emphasize the approaches used in braille education and their importance. Bola et al. (2016) showed that literate adults can learn to read braille with proper methods and high motivation, with most participants able to read full words in braille at an average speed of six words per minute. A study by Herzberg et al. (2023) did find improvements in post-training exam scores for Nemeth code teachers, but emphasized the continued need for professional development and additional resources to build teachers ' skills in Nemeth code. Additionally, a study by Herzberg, Rosenblum and Robbins (2017) suggests that student motivation and confidence are important factors in determining whether students should switch from print to braille, as well as the need for a comprehensive curriculum for print readers switching to braille.

In conclusion, technology and effective teaching approaches are key to improving braille literacy education. Technological tools such as BrailleBunny, mobile apps, and AI-based tutors can provide a more interactive and effective way to learn braille. At the same time, a teaching

approach tailored to individual needs, as well as ongoing professional support for teachers, is essential to ensure that students with vision problems can reach their full potential in braille literacy. The combination of technology and innovative teaching approaches can have a significant impact in improving braille literacy worldwide.

Discussion

This study examines two main themes in braille education, namely technology for braille education and approaches in braille education. In the context of braille education, the role of technology and effective approaches is a central focus for improving braille literacy among visually impaired individuals. The use of advanced devices and mobile applications, as well as effective pedagogical approaches, have been shown to have a significant effect in helping braille learners achieve higher levels of literacy. This study aims to examine the latest developments in these two themes and evaluate the effectiveness of the efforts that have been undertaken.

In the theme of technology, the study found that the development of devices such as BrailleBunny and mobile applications Reading and Writing Adventure Time! has played an important role in advancing braille learning in the Philippines and Canada. The Braillebunny, which was developed through a joint design process with the end user, received positive feedback despite some shortcomings such as durability and cost issues. Mobile apps, on the other hand, show positive results in supporting students' braille reading skills, despite requiring significant technical support. In addition, the use of artificial intelligence tutors for braille teaching has shown effectiveness in helping students learn braille contractions more quickly and consistently when used alongside lessons from teachers.

Overall, the theme of technology in braille education suggests that the use of innovative mobile devices and applications can improve braille literacy among students. Despite some challenges such as cost and technical support requirements, the potential of this technology to improve braille reading skills is significant. This study emphasizes the need to continuously improve and support the use of technology in braille education to achieve greater effectiveness.

Under the theme of approaches in braille education, studies emphasize the experience of teachers in teaching students who use print and braille media. Braille recognition is usually done around the age of 7.8, and studies show the importance of student motivation as well as factors such as diagnosis and reading stamina in determining the transition from print to braille. In addition, studies have found that visually impaired individuals can effectively learn braille if given the appropriate motivation and approach, even if they do not have high tactile acuity. Online professional development for teachers in the context of Unified English Braille (UEB) has also shown improvements in teacher knowledge and skills, although there are still some challenges in the use of Nemeth code that require further training.

In conclusion, the approach in braille education emphasizes the importance of student motivation and an effective pedagogical approach. The introduction of braille at the right age, as well as appropriate support and training for teachers, is key in ensuring the effectiveness of braille education. This study shows that with the right motivation and appropriate approach, visually literate individuals can also learn braille effectively. However, there is still a need to

improve training and support in the use of Nemeth codes to ensure the success of comprehensive braille education.

Overall, the study emphasizes the importance of technology and the right approach in braille education. The use of innovative devices and applications, as well as effective pedagogical approaches, are key to improving braille literacy among visually impaired individuals. However, challenges such as cost, technical support requirements, and the need for further training in the use of Nemeth code require constant attention and effort. By enhancing and supporting these efforts, we can achieve significant improvements in braille literacy and provide a more inclusive education for all.

Conclusion

This study has successfully explored two major themes in braille education: technology and approaches in braille education. The results of this study confirm that the integration of innovative technologies and effective pedagogical approaches is essential to improve braille literacy among visually impaired individuals. Additionally, these findings emphasize the need to continually improve and adapt teaching technologies and approaches to align with the specific needs of braille students.

The objective of this study was to analyze the impact of technological advances and teaching methodologies in braille education. This objective has been achieved through a thorough examination of various technological innovations such as BrailleBunny and the Reading and Writing Adventure Time Mobile App!, as well as a pedagogic approach involving teacher experience and professional development in Unified English Braille (UEB). This study provides valuable insights into how these tools and methods contribute to improving braille literacy. The results of this study also pave the way for further research in this area, in particular in measuring the long-term effects of introduced technologies and teaching methodologies.

This study makes a significant contribution to the field of braille education by highlighting the positive impact of technology and effective teaching strategies. The findings underscore the potential of devices such as BrailleBunny and artificial intelligence tutor in accelerating braille learning, despite challenges such as cost and durability. Furthermore, the study emphasizes the importance of motivating students and providing an appropriate learning environment, which is key to the success of braille education. Views on professional development for teachers also contribute to improving the quality of braille teaching. The study also shows that investments in educational technology and ongoing teacher training are essential to ensure long-term effectiveness.

Future studies should focus on addressing the challenges identified in this study, such as improving the robustness and cost-effectiveness of braille learning devices as well as providing ongoing technical support for mobile applications. Further studies should also explore further training for teachers in using Nemeth code and other specialized braille codes. In addition, longitudinal studies can provide deeper insights into the long-term effects of these technologies and approaches on braille education. Moreover, future research may evaluate the effectiveness of different approaches in different cultural and economic contexts to produce more comprehensive guidance.

The study is in line with SDG 4, which aims to ensure inclusive and quality education and promote lifelong learning opportunities for all. By improving braille education through innovative technologies and effective teaching methods, the study supports the goal of providing quality education to visually impaired individuals. Ensuring these students have access to the appropriate tools and approaches is an important step towards achieving quality inclusive education. With this, we can build a more inclusive society and provide equal opportunities to all individuals, in line with SDG 4's vision for equitable and quality education.

Acknowledgments

References

Alwashmi, K., Meyer, G., Rowe, F., & Ward, R. (2024). Enhancing learning outcomes through multisensory integration: A fMRI study of audio-visual training in virtual reality. *NeuroImage*, *285*, 120483. https://doi.org/10.1016/j.neuroimage.2023.120483

Alya Qasdina Ng Ai Lee, & Kway, E. H. (2023). Fuzzy Delphi Method (FDM) to identify elements , constructs , and items for designing and developing contents for pre-braille skills module. *International Journal of Advanced Research in Education and Society*, *5*(1), 117–126.

Amoah, D. K. (2022). Advances in the understanding and enhancement of the human cognitive functions of learning and memory. *Brain Science Advances*, *8*(4), 276–297. https://doi.org/10.26599/bsa.2022.9050023

Bhat, R. A. (2023). The impact of technology integration on student learning outcomes: A comparative study. *International Journal of Social Science, Educational, Economics, Agriculture Research and Technology*, *2*(9), 592–596. https://doi.org/10.54443/ijset.v2i9.218

Bola, L., Siuda-Krzywicka, K., Paplinska, M., Sumera, E., Hanczur, P., & Szwed, M. (2016). Braille in the sighted: Teaching tactile reading to sighted adults. *Plos One*, *11*(5). https:// doi.org/10.1371/journal.pone.0155394

Creswell, J. W. (2013). Qualitative inquiry & research design choosing among five approaches third edition. In *Health Promotion Practice*. SAGE Publications.

Croake, K., Gentle, F., & Duncan, J. (2024). Evidence-based pedagogy used to teach beginning readers braille in a mainstream setting: A scoping review. *British Journal of Visual Impairment*, 1–16. https://doi.org/10.1177/02646196241250200

Englebretson, R., Holbrook, M. C., & Simon, F.-B. (2023). A position paper on researching braille in the cognitive sciences: Decentering the sighted norm. *Applied Psycholinguistics*, *44*, 400–415. https://doi.org/10.1017/s0142716423000061

Geel, M., Keuning, T., Meutstege, K., de Vries, J., Visscher, A., Wolterinck, C., Schildkamp, K., & Poortman, C. (2023). Adapting teaching to students' needs: What does it require from teachers? In *Effective Teaching Around the World* (pp. 723–736). Springer International Publishing. https://doi.org/10.1007/978-3-031-31678-4_33

Haase, S. C. (2011). Systematic reviews and meta-analysis. *Plastic and Reconstructive Surgery*, *127*(2), 955–966. https://doi.org/10.1097/PRS.0b013e318200afa9

Hasan, M., Khan, A. N., & Malik, I. S. (2023). Universal Design for Learning (UDL): A paradigm shift in inclusive education. *Journal of Education and Practice*, *3*(5), 134–137. https://doi.org/10.7176/jep/14-25-01

Herzberg, T. S., Rosenblum, L. P., Osterhaus, S. A., Larkin, S. K., & McBride, C. R. (2023). Online synchronous professional development to support teachers of students with visual impairments in learning Nemeth Code within Unified English Braille contexts. *Journal of Visual Impairment & Blindness*, *117*(6), 440–452. https://doi.org/10.1177/0145482 X231216956

Herzberg, T. S., Rosenblum, L. P., & Robbins, M. E. (2017). Teachers' experiences with literacy instruction for dual-media students who use print and braille. *Journal of Visual Impairment and Blindness*, *111*(1), 49–59. https://doi.org/10.1177/0145482x1711100 105

Hong, Q. N., Fabregues, S., Bartlett, G., Boardman, F., Cargo, M., Dagenais, P., Gagnon, M.-P., Griffiths, F., Nicolau, B., O'Cathain, A., Rousseau, M.-C., Vedel, I., & Pluye, P. (2018). The Mixed Methods Appraisal Tool (MMAT) version 2018 for information professionals and researchers. *Education for Information*, *34*(4), 285–291. https://doi. org/10.3233/EFI-180221

Hoskin, E. R., Coyne, M. K., White, M. J., Dobri, S. C. D., Davies, T. C., & Pinder, S. D. (2024). Effectiveness of technology for braille literacy education for children: A systematic review. *Disability and Rehabilitation: Assistive Technology*, *19*(1), 120–130. https://doi.org/10.1080/17483107.2022.2070676

Hoskin, E. R., Pinder, S. D., & Davies, T. C. (2024). Development of BrailleBunny: A device to enhance braille learning. *Disability and Rehabilitation: Assistive Technology*, *19*(4), 1610–1625. https://doi.org/10.1080/17483107.2023.2224404

Kamei-Hannan, C. (2023). Reflections on the design, development, and implementation of a braille mobile app. *Assistive Technology Outcomes and Benefits*, *17*, 57–75. https://www. scopus.com/inward/record.uri?eid=2-s2.085163159545&partnerID=40&md5=b74bf26 493aad823c75fbe2f261846a7

Kana, F. Y., & Hagos, A. T. (2024). Factors hindering the use of braille for instruction and assessment of students with visual impairments: A systematic review. *British Journal of Visual Impairment*. https://doi.org/10.1177/02646196241239173

Kraus, S., Breier, M., & Dasi-Rodriguez, S. (2020). The art of crafting a systematic literature review in entrepreneurship research. *International Entrepreneurship and Management Journal*, *16*(3), 1023–1042. https://doi.org/10.1007/s11365-020-00635-4

Linnenluecke, M. K., Marrone, M., & Singh, A. K. (2020). Conducting systematic literature reviews and bibliometric analyses. *Australian Journal of Management*, *45*(2), 175–194. https://doi.org/10.1177/0312896219877678

Mantzoukas, S. (2008). Facilitating research students in formulating qualitative research questions. *Nurse Education Today*, *28*(3), 371–377. https://doi.org/10.1016/j.nedt.2007. 06.012

Martiniello, N., & Wittich, W. (2022). The association between tactile, motor and cognitive capacities and braille reading performance: A scoping review of primary evidence to advance research on braille and aging. *Disability and Rehabilitation*, *44*(11), 2515–2536. https://doi.org/10.1080/09638288.2020.1839972

McCarthy, T., Rosenblum, L. P., Johnson, B. G., Dittel, J., & Kearns, D. M. (2016). An artificial intelligence tutor: A supplementary tool for teaching and practicing braille. *Journal of Visual Impairment and Blindness*, *110*(5), 309–322. https://doi.org/10.1177/ 0145482x1611000503

Mohamed Shaffril, H. A., Samsuddin, S. F., & Abu Samah, A. (2021). The ABC of systematic literature review: the basic methodological guidance for beginners. *Quality and Quantity*, *55*(4), 1319–1346. https://doi.org/10.1007/s11135-020-01059-6

Mondesir, B., & Griffin, R. A. (2020). A balanced approach to literacy instruction and support for diverse learners. *Georgia Journal of Literacy*, *43*(1), 30–48. https://doi.org/10.56887/ galiteracy.17

Parween, S., & Dheesha, J. . (2018). Curriculum for students with visual impairment in inclusive setup. In *Inclusive Education for Persons with Disabilities: A Methodical Guide Book* (pp. 125–136). https://doi.org/10.5220/0008434306020612

Petticrew, M., & Roberts, H. (2006). *Systematic reviews in the social sciences*. Wiley. https:// doi.org/10.1002/9780470754887

Shalini, K. V., Keerthi, B., Manasa, B., Padmashree, & Ashritha, K. G. (2020). Design and implementation of digital braille system for the visually impaired. *International Journal of Computer Trends and Technology*, *68*(3), 80–83. https://doi.org/10.14445/22312803/ ijctt-v68i3p116

Susanti, D. J., & Rudiyati, S. (2019). Learn writing and reading braille for elementary student with visual impairment: A systematic review. *Advances in Social Science, Education and Humanities Research*, *296*, 176–180. https://doi.org/10.2991/icsie-18.2019.33

Tisnawati, N. F., Yuliati, & Purbaningrum, E. (2022). Braille innovation technology in teaching and learning process for visual impairment. *Jurnal Teknologi Pendidikan*, *24*(2), 224–235. https://doi.org/10.21009/jtp.v24i2.24971