

Empowering Blind Children through Future Technology: Protective Factors Associated with AI-Based Audio and Braille Dictionaries in English Learning

Yuli Nuranawati¹, Urai Salam¹, Venny Karolina¹, Aunnurrahman¹, Eka Ariyati¹

¹ Universitas Tanjungpura, Indonesia

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ABSTRACT

This study investigates how an AI-integrated Braille and audio dictionary supports academic resilience among blind students learning English. Employing a qualitative phenomenological design, the study involved seven blind tenth-grade students from two special schools in West Kalimantan, Indonesia, along with parents, English teachers, and school principals. Data were gathered through in-depth interviews, focus group discussions, classroom observations, and documentation, then analyzed thematically using Masten's resilience theory, Ungar's resource negotiation perspective, and Bronfenbrenner's Ecological Systems Theory. Findings reveal three interrelated themes: (1) AI-supported audio features fostered individual protective factors, including persistence, self-efficacy, and adaptive problem-solving; (2) the Braille-audio integration functioned as a protective technological resource by enhancing multisensory learning, autonomy, and pronunciation accuracy; and (3) resilience was strengthened through teacher and parental environmental support. The study proposes a Digital Resilience Framework highlighting how internal capacities, accessible technology, and ecological support interact to sustain blind learners' engagement in English learning. These findings contribute to inclusive education literature by demonstrating that assistive AI technologies serve not only as learning tools but as resilience-enhancing resources for students with visual impairments.

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Corresponding Author:

Yuli Nuranawati
Universitas Tanjungpura, Indonesia; f2151241021@student.untan.ac.id

1. INTRODUCTION

Education is a universal human right for every citizen without exception, including for Children with Special Needs (ABK). In Indonesia, the legal basis for inclusive education has been expressly regulated in Law Number 20 of 2003 concerning the National Education System, Article 5 paragraph (2), which states that citizens with physical, emotional, mental, intellectual, or social disabilities have

the right to receive special education. This policy is reinforced through Government Regulation Number 13 of 2020, which requires every educational unit to provide appropriate accommodations for persons with disabilities in order to realize an inclusive education system that is equal and just.

Even though regulations related to inclusive education are available, their implementation still faces various challenges (Sibagariang et al., 2025). Government Regulation Number 70 of 2009 even mandates the provision of at least one inclusive school in every district/city. However, the gap in access to education for children with special needs remains quite large. Data from the Central Statistics Agency (BPS) in 2024 showed that 17.85% of children with disabilities aged five and over did not receive formal education, significantly higher than the 5.04% of children without disabilities. This situation is often caused by limited regular school infrastructure, a lack of educators with special education backgrounds, and a lack of accessible learning media such as Braille books or audio-based media (Rahmayani & Selian, 2025). On the other hand, one of the important competencies needed by students to compete in the global era is mastery of English, both orally and in writing (Ulasheva, 2025). Based on research (Khoiruman et al., 2025). English communication skills not only improve the quality of social interactions but also open up broader job opportunities in the future. In the modern workplace, most recruitment platforms and professional information sources use English as their primary language. Therefore, English proficiency is a crucial skill for all students, including those with special needs.

However, for visually impaired children, both low-vision and totally blind, the English learning process presents its own complexities. Differences in spelling between Indonesian and English often present obstacles to mastering vocabulary, grammar, and pronunciation (Fitria, 2025). Research (Hajam & Puju, 2025). The visual limitations of blind students also complicate the process of understanding written forms and word structures in English, so a more adaptive and accessible learning approach is needed. One approach that can be used is the multisensory approach (Shidqi & Budi, 2023). A multisensory approach is a learning strategy that utilizes various sensory channels such as vision, hearing, movement and touch to strengthen the learning process (Carreker & Birsh, 2019).

For blind students, this approach places greater emphasis on using the senses of hearing and touch as the primary learning channels. In this context, the use of Braille and audio media becomes crucial. Braille is a raised writing system based on a combination of six dots that enables blind students to read and write through their sense of touch (Millar, 2008). Through Braille, students can access written text independently and build an understanding of word structure, grammar, and spelling (Awang et al., 2025). In addition to Braille, audio media also plays an important role in English learning for blind students. Audio media presents information through sound stimuli, helping students understand pronunciation, intonation, and rhythm (Nisa'in Prihnaharin et al., 2019). Developments in digital technology have also opened up opportunities for the use of Artificial Intelligence (AI) in language learning through text-to-speech and voice recognition features. This technology allows for more accurate pronunciation, resembling native speakers, thereby helping students better understand English phonology (Luckin et al., 2016). Recent research by Villalba et al. (2024) developed an accessible English-learning application that integrated AI-supported audio interaction and accessibility features, finding that such technologies enhanced learner engagement, accessibility, and independent learning opportunities. These findings suggest that the integration of AI-generated audio with Braille-based resources can create a more accessible and autonomous learning environment for blind students, supporting both language acquisition and active participation in learning.

The integration of AI-generated audio with Braille resources also aligns with the principles of multimodal learning. According to Mayer's Cognitive Theory of Multimedia Learning, learning becomes more effective when information is processed through multiple sensory channels, enabling learners to construct richer mental representations of the learning content (Mayer, 2009). This principle is particularly relevant for students with visual impairments, who depend on alternative sensory modalities to access information. Recent research involving children with visual impairments has further shown that multimodal learning environments utilizing different sensory modalities can

improve comprehension and accessibility by providing alternative pathways for information processing (Valente et al., 2024). Therefore, the combination of tactile Braille input and AI-generated auditory support has the potential to create a richer, more accessible, and more autonomous English-learning environment for blind students.

Appropriate learning media support not only impacts cognitive aspects but also psychological aspects of students, particularly in building academic resilience. Resilience refers to an individual's ability to adapt positively when faced with difficulties or pressure (Masten et al., 1990). In the context of education, academic resilience describes a student's capacity to persist and strive to achieve learning success despite facing various obstacles (Martin & Marsh, 2006). One important factor in the formation of resilience is the existence of protective factors originating from the learning environment and from the individual's internal resources (Rutter, 2012). In educational settings, academic resilience enables students to maintain motivation, regulate emotions, and continue learning despite obstacles. For students with visual impairments, resilience is shaped by environmental support systems, including inclusive pedagogy and accessible learning tools. Protective factors such as teacher support, family involvement, and assistive technology help mitigate academic risk. Social support is crucial in fostering resilience and mitigating risk for students with disabilities (Manitsa & Doikou, 2022). Research in educational psychology has shown that social support is correlated with higher levels of resilience among students facing adversity (Hajam & Puju, 2025). Furthermore, qualitative research by Inayah (2021) demonstrated that blind students develop adaptive coping strategies by utilizing assistive technologies such as screen readers to participate in formal learning activities. The study revealed that Braille and audio-based technologies function not merely as technical tools but as meaningful resources that foster autonomy, self-efficacy, and positive learning experiences. From a resilience perspective, these technologies may be understood as protective resources that help learners negotiate educational barriers and sustain academic engagement. Consistent with this view, previous studies have shown that assistive technologies can enhance the academic participation of blind students and create more meaningful learning experiences (Alper & Raharirina, 1995).

Although previous studies have explored the use of Braille, audio media, and assistive technologies to support learning among blind students, research examining the integration of Braille dictionaries with AI-generated audio for English learning remains limited, particularly in the Indonesian context. Most existing audio-based learning resources rely on prerecorded human voice recordings, which require considerable time and effort to produce, update, and expand. In contrast, AI-generated audio based on text-to-speech technology enables the rapid production of consistent and natural English pronunciation across a wide range of vocabulary items, thereby improving accessibility and scalability. When combined with Braille, this technology creates a multimodal learning environment that engages both tactile and auditory channels, potentially enhancing learner autonomy, self-efficacy, and academic resilience. The novelty of this study lies in the integration of a Braille dictionary with AI-generated pronunciation audio developed through Google AI Studio, providing a more scalable and accessible learning resource than conventional prerecorded audio materials. Therefore, this study seeks to explore how the use of an AI-generated audio-Braille dictionary functions as a protective resource that supports the development of academic resilience among blind students in English learning.

2. METHODS

This study employed a qualitative phenomenological approach to explore the lived experiences of blind students in utilizing an AI-generated audio-integrated Braille dictionary for English learning, particularly in Analytical Exposition Text materials. A phenomenological design was selected to gain a deeper understanding of students' perceptions, emotional responses, adaptive strategies, and the development of academic resilience within authentic learning contexts.

The study was conducted at Mempawah State Special School and Rasau Jaya State Special School, West Kalimantan, Indonesia. Preliminary observations were undertaken in October 2025, while the

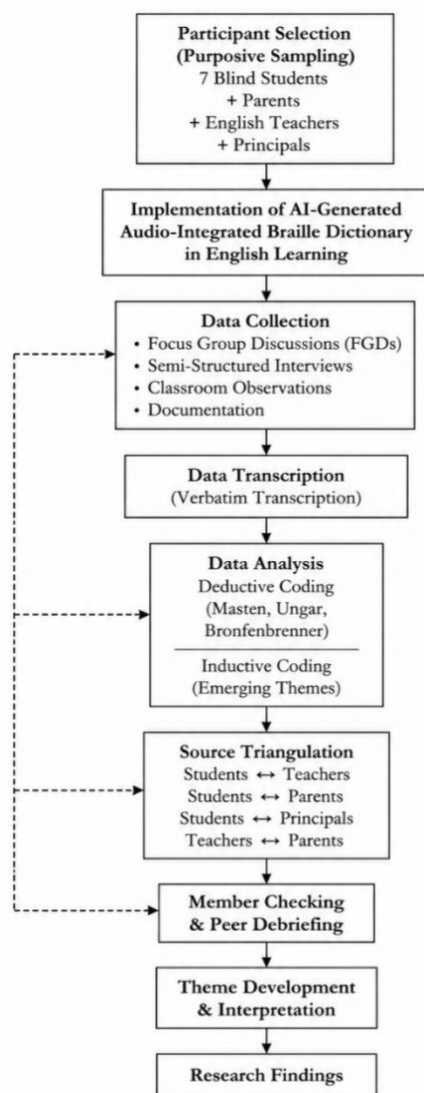
main data collection was conducted from February 11–19, 2026. Participants were selected using purposive sampling based on the following criteria: (1) being blind students capable of reading Braille fluently and (2) having prior experience using an AI-generated audio-integrated Braille dictionary in English learning. The primary participants consisted of seven Grade 10 blind students (three from Mempawah and four from Rasau Jaya). To strengthen contextual understanding and data triangulation, additional participants included six parents, two English teachers, and two school principals.

The AI component of the dictionary consisted of pronunciation audio generated through Google AI Studio using artificial intelligence-based text-to-speech technology. The generated audio files were linked to QR codes embedded in the Braille dictionary, allowing students to access English pronunciation support through mobile devices. While the QR codes functioned as the access mechanism, the AI component was embedded in the generation of speech output, providing consistent and scalable pronunciation models for vocabulary learning.

Data were collected through Focus Group Discussions (FGDs), semi-structured interviews, classroom observations, and documentation. The interview protocol was developed based on Masten's resilience theory, Ungar's resource negotiation perspective, and Bronfenbrenner's Ecological Systems Theory. Data collection focused on two dimensions: (1) individual resilience, including persistence, self-efficacy, and adaptive problem-solving skills; and (2) external protective factors, including access to resources, ecological support, and the contextual relevance of learning media.

Data analysis followed the interactive model of Miles and Huberman, consisting of data reduction, data display, and conclusion drawing and verification. All interviews, FGDs, and observation records were transcribed verbatim prior to analysis. The coding process combined deductive and inductive approaches. Deductive coding was guided by theoretical constructs derived from resilience theory, resource negotiation theory, and ecological systems theory, including categories such as self-efficacy, persistence, learning autonomy, access to resources, teacher support, and parental support. Inductive coding was subsequently employed to identify emerging themes that reflected participants' lived experiences beyond the predefined framework. Similar codes were grouped into categories and then synthesized into broader themes through an iterative comparison process.

To ensure trustworthiness, source triangulation was conducted by comparing data obtained from students, teachers, parents, and school principals. Member checking was performed with selected participants to verify the accuracy of interpretations, while peer debriefing was used to review coding consistency and thematic development. Ethical principles were maintained through informed consent, confidentiality, anonymity, and voluntary participation throughout the study.

Picture 1. Methodological Framework of the Study

3. FINDINGS AND DISCUSSION

The qualitative data analysis results were obtained through a thematic analysis process, which included open coding, axial coding, and selective coding. This process was conducted to identify patterns of meaning that emerged from interview data, observations, and documentation related to the learning experiences of blind students using an Artificial Intelligence (AI)-based Braille dictionary.

In the selective coding stage, various meaningfully related categories were integrated into main themes that comprehensively represent students' learning experiences. These categories reflect aspects of individual resilience, learning strategies, access to resources, social support, learning accessibility, language competency development, and obstacles encountered during the learning process. The following are the results of selective coding:

Table 1. Selective Coding adapting from team model (Salam, 2012, pp.225-240)

Category	Description
individual resilience	Never give up Keep learning Self-motivation Ability to overcome difficulties
adaptive learning strategies	Independence Time management
resource access	The role of assistive technology Access the AI Braille dictionary Availability of learning resources
social support	Learning support ecosystem Looking for a teacher/friend Family support Academic social interaction
Learning accessibility	Inclusiveness Disability-friendly facilities
improving language competence	Improve vocabulary skills Increased self-confidence
obstacles and evaluation	Limited learning facilities Dictionary development needs

The qualitative data analysis in this study was obtained from interviews, observations, and documentation, which were analyzed through a selective coding stage to identify core categories and main themes. This stage aims to integrate various codes into broader concepts to comprehensively describe students' learning experiences. Category classification is based on recurring patterns and emerging meanings from the data, reflecting academic resilience, learning strategies, and contextual support in the learning process (see Table X).

Individual Resilience emphasizes students' internal strengths in facing various learning challenges. This category encompasses a never-give-up attitude, a continued effort to learn, self-motivation, consistency in learning, and the ability to overcome difficulties during the learning process.

Adaptive Learning Strategies demonstrate students' ability to adapt learning strategies to their needs. This includes learning independence, time management, study discipline, the use of independent learning strategies, and the ability to adapt learning methods to enhance understanding.

Resource Access highlights the crucial role of learning resources in supporting the learning process. Learners utilize assistive technology, such as AI-based Braille dictionaries, digital media, and various other easily accessible learning resources to help them understand the material.

Social support describes the influence of the surrounding environment on supporting learning success. This category includes a supportive learning ecosystem, interactions with teachers and peers, collaboration in learning, and family support, both emotional and academic.

Learning Accessibility focuses on inclusivity in the learning process. This includes the availability of accessible materials, adapting learning to meet student needs, and providing facilities that support learning for students with special needs.

Improved language competence demonstrates the results of the learning process. Students experience improvements in vocabulary mastery, language comprehension, communication skills, and increased confidence in using language.

Obstacles and Evaluation identified various challenges encountered during the learning process and the need for future improvements. These challenges include limited learning facilities, technical challenges in media use, limited access to technology, and the need for further development of learning media such as Braille-based dictionaries.

At the next level of analysis, these categories were interpreted to understand the relationships between internal factors (such as motivation and resilience), external factors (such as social support and technology), and learning outcomes. These findings suggest that academic resilience is influenced not only by individual abilities but also by the interaction between adaptive learning strategies, access to resources, and a supportive learning environment.

The analysis results show that most students demonstrate persistence in overcoming difficulties in learning English. When they encounter difficulties understanding vocabulary, pronunciation, or using an AI-based Braille dictionary, students tend not to give up and continue trying until they succeed. This is reflected in one student's statement, "If it's difficult, I try again until I can do it" (S1, Interview). This statement demonstrates a never-give-up attitude as part of individual resilience in the learning process.

Similar findings were also reinforced by the experiences of other students who encountered technical difficulties in using learning media. One student explained that when the audio from the QR code didn't work, he kept trying to repeat the process until it worked. He stated, "If the audio doesn't work, I try again until it works" (S2, Interview). This statement indicates that students not only faced difficulties but also actively sought solutions to the obstacles that arose.

In addition to demonstrating perseverance, the use of an AI-based Braille dictionary also encourages increased student self-efficacy in learning English. Students feel more confident because they can independently access word meanings, spelling, and pronunciation. One student stated, "If I encounter a difficult word, I look it up in the dictionary until I find it" (S3, Interview). This statement indicates that students are beginning to develop independence in learning without relying entirely on the teacher.

During the learning process, students also demonstrated adaptive learning strategies, particularly in problem-solving. They did not rely solely on one source, but utilized various alternatives to understand the material. One student stated, "If there's a word I don't understand, I ask a friend" (S4, Interview). Furthermore, other students utilized additional technology as a learning resource, as expressed in the statement, "I search on Google or use other apps like Duolingo" (S5, Interview). This demonstrates students' ability to adapt and find solutions independently.

In this context, an AI-based Braille dictionary serves as a crucial resource supporting the learning process of blind students. This tool allows students to access learning through multisensory channels, namely through touch (Braille) and hearing (audio). Some students even described this tool as a very helpful tool in understanding vocabulary. This demonstrates that technology serves not only as an assistive tool but also as a factor in strengthening students' academic resilience.

In addition to individual factors, environmental support also plays a significant role in the learning process. Teachers act as facilitators, assisting students in using the Braille-AI dictionary, particularly in finding vocabulary and accessing audio. One student stated, "The teacher helped me find the initial letter of the vocabulary word and the barcode scanning position" (S6, Interview). This support provides a sense of security and increases students' confidence in using learning technology.

Family support is also a crucial factor in strengthening students' learning at home. Parents play a key role in supporting their children and helping them review learning materials. This is evident in one parent's statement, "I accompany my child while studying at home and help them review the audio" (Parent S1, Interview). This support demonstrates the synergy between the school and family environments in supporting student learning success.

However, this study also identified several barriers to the learning process. Limited facilities, such as a lack of language laboratories and limited teaching staff, pose challenges for schools. However, the use of an AI-based Braille dictionary helps mitigate these barriers by providing more accessible learning resources for students.

Overall, the findings of this study indicate that students are not merely passively engaged, but actively construct their understanding through persistence, adaptive learning strategies, and the use of technology. Although students have not yet fully demonstrated in-depth critical reasoning in the initial

stages, they have demonstrated engagement through experiences, responses, and efforts to overcome learning difficulties. This indicates that the learning process does not stop at the basic understanding stage, but continues to develop toward building stronger academic resilience.

Table 2. Thematic Matrix of FGD (Focus Group Discussion) Results

Research Focus	FGD Results	Indicator
Student responses to the Braille-AI dictionary	Adaptive and positive responses to the use of assistive technology	Increased self-confidence; retrying audio features when incorrect; actively asking questions; initiative to use the dictionary independently
Emerging protective factors	Multidimensional protective factors (individual, technological, social)	Individual: persistence, self-regulation, increased self-efficacy; Technology: tactile Braille and audio AI integration, high accessibility; Social: teacher support in the classroom and parent assistance at home
The role of dictionaries in overcoming the challenges of learning English	Dictionary as a cognitive and psychological mediator	Pronunciation is more accurate; vocabulary comprehension is increased; learning independence is developed; learning anxiety is reduced
Obstacles faced	Technical and contextual barriers	QR code disruption/technical error; limited school facilities; adaptation time for use; limited supporting devices
Interpretation of teachers and parents	Contribution to the gradual improvement of academic resilience	Students do not give up easily; their motivation to learn increases; they are more active when practicing speaking; they show consistency in practice.

Thematically, increased student persistence and self-efficacy appear to correlate with two main conditions: (1) easy access to the dictionary's multisensory features (tactile Braille and AI audio), and (2) direct support from teachers and parents during the learning process. In student group discussions, statements such as "if I can't do it, I'll try again" or "if it doesn't make a sound, I'll ask the teacher for help first and then try again myself" indicate a relational adaptation pattern. This means that the effort to try again is not only driven internally, but is also influenced by a sense of security and social support in the immediate environment.

In the teacher and parent focus groups, it was confirmed that students were more willing to try when they knew help was available if needed. Teachers stated that after several uses, students began scanning the QR code independently before asking for help. Parents also reported that their children were more willing to open dictionaries at home without being asked.

Discussion

This study yielded two main themes: individual student resilience and external protective factors in learning English using an AI-based Braille dictionary. These two themes are not isolated but interact to shape the academic resilience of blind students. The first theme, individual resilience, demonstrates students' ability to persevere and adapt to various learning difficulties. This is reflected in their perseverance, self-motivation, and problem-solving skills demonstrated throughout the learning process. Students do not passively confront obstacles but actively seek solutions, either through repetition, independent exploration, or interaction with others. From a thematic analysis perspective,

this pattern demonstrates the consistent emergence of persistence and adaptive coping themes in the data.

This result is in line with the resilience theory put forward by (Masten et al., 1990), which states that resilience is an individual's capacity to adapt positively to difficult circumstances. Students' persistence in trying again when faced with difficulties indicates a strong task orientation, while increased confidence in using the Braille-AI dictionary reflects growing self-efficacy. These two aspects are important components in developing academic resilience.

This discussion focuses on how the AI-generated audio-Braille dictionary functions as a protective factor in supporting resilience among blind students learning English (Septiani & Fitria, 2016). The findings indicate that resilience does not emerge solely from individual abilities but develops through the interaction between students' adaptive capacities, accessible technological resources, and social support from their immediate environment. This interpretation is consistent with Ungar's resource negotiation perspective, which views resilience as a dynamic process shaped by individuals' ability to access and utilize meaningful resources within their social contexts (Ungar, 2011). In this study, the AI-generated audio-Braille dictionary served as such a resource by providing accessible pronunciation support that students could independently navigate. Consequently, resilience emerged not only because students possessed adaptive capacities but also because they successfully negotiated access to a resource that reduced learning barriers, expanded learning opportunities, and strengthened engagement in English learning.

Research shows that blind students exhibit high levels of persistence when facing difficulties in understanding English vocabulary and when experiencing technical difficulties when using an AI-based Braille dictionary. Most students reported that they tended to try again when they encountered difficulties, rather than immediately abandoning the learning process. This attitude indicates the presence of adaptive coping strategies that are part of the process of developing academic resilience. This aligns with resilience theory, which states that resilience is a positive adaptation process that emerges when individuals face challenging or risky conditions (Masten et al., 1990). In English language learning for blind students, limited access to visual information is a structural risk factor that can impact the learning process. However, the students' continued efforts to understand vocabulary through Braille dictionaries and AI audio demonstrate their ability to develop adaptive responses to these barriers.

In addition to persistence, increased self-efficacy was also evident in students' learning experiences when using the AI-based Braille dictionary. Many students reported feeling more confident in understanding English vocabulary and pronunciation than before using the tool. This sense of ability to complete learning tasks independently indicates a growing belief in one's own abilities. This finding aligns with Bandura's self-efficacy theory, which states that an individual's perception of their competence significantly influences motivation, persistence, and success in facing challenging tasks (Kroshus et al., 2021). In this study, the experience of using a Braille dictionary integrated with AI-based audio provided students with a concrete mastery experience, strengthening their confidence in their ability to independently understand English language materials. Thus, assistive technology not only plays a role in improving cognitive abilities but also strengthens psychological dimensions related to self-confidence and learning motivation.

More importantly, the findings suggest that self-efficacy was not merely an internal characteristic possessed by students but was facilitated by the availability of AI-generated audio support. Through repeated access to pronunciation models and vocabulary explanations, students experienced successful task completion independently. These mastery experiences gradually strengthened their confidence in learning English, suggesting a pathway through which an external technological resource contributed to the development of an internal protective factor. This finding highlights the dynamic interaction between technology and learner psychology in fostering academic resilience.

The second theme, external protective factors, demonstrates that the environment plays a significant role in supporting students' academic resilience. An AI-based Braille dictionary is a key

protective factor, helping students overcome limitations in understanding English vocabulary. In the context of thematic analysis, this theme emerged as access to resources, which plays a role in reducing learning barriers.

The results of this study also show that students develop various adaptive problem-solving strategies when facing learning difficulties. Students do not rely solely on a single source of assistance, but utilize various strategies such as asking teachers or friends, searching for vocabulary through the Braille index, scanning QR codes to access audio, and utilizing other digital technologies such as language learning apps or online search engines. This behavioral pattern indicates that students have the ability to independently find solutions through various available learning resources. These adaptive strategies demonstrate that students are able to gradually develop learning autonomy. This finding aligns with previous research showing that assistive technology in inclusive education can increase learning engagement and encourage academic independence in students with disabilities (Ghilay & Ghilay, 2013).

In resilience theory, the presence of an AI-based Braille dictionary can be understood as a protective factor that helps mitigate the impact of educational risks faced by blind students. According to Masten's protective factor framework, resources that reduce risk exposure or enhance an individual's adaptive abilities can contribute significantly to the development of resilience (Cassidy, 2016). In this study, an AI-based Braille dictionary provided students with direct access to word meanings, pronunciations, and example sentences independently. This reduced students' dependence on direct teacher assistance and enabled them to access information more flexibly. The results of this study align with previous research showing that the use of assistive learning technology can improve the academic participation and learning independence of blind students in inclusive education contexts. (Arifin et al., 2024). Unlike conventional prerecorded audio materials, the AI-generated pronunciation audio provided scalable and consistent language input that could be expanded to accommodate additional vocabulary without requiring extensive manual recording. This characteristic makes the technology particularly relevant as a sustainable educational resource for learners with visual impairments. Consequently, the technological resource not only supported language acquisition but also contributed to resilience by reducing dependency and increasing learning autonomy. In addition, research (Primadhita Nugraheni et al., 2025) shows that students can develop literacy skills, increase participation in learning activities, and build self-confidence in learning using Braille media.

From a learning perspective, the integration of Braille as tactile input and AI audio as auditory output also aligns with multimodal learning theory. According to Mayer, the learning process is more effective when information is delivered through more than one sensory channel, as this can enhance cognitive processing and information retention (Mayer & Richard E, 2009). In this study, the combination of tactile and auditory experiences enabled students to understand English vocabulary more comprehensively. This finding also aligns with previous research showing that technologies such as screen readers, speaking dictionaries, and AI-based learning applications can improve vocabulary acquisition and learning independence in blind students (Rahmayani & Selian, 2025). Thus, the AI-based audio Braille dictionary not only acts as a learning aid, but also as a means of strengthening students' psychological resilience in facing academic challenges.

However, this study also revealed limitations in educational infrastructure, such as a lack of language laboratory facilities and limited English language learning resources in schools. This situation indicates that environmental factors remain a challenge in supporting English learning for blind students. The socio-ecological perspective on resilience explains that individual resilience is greatly influenced by the availability of resources in their social environment (Enung et al., 2022). In resource-constrained environments, assistive technologies such as AI-based Braille dictionaries can serve as alternative resources that help students access learning information more independently (Wau et al., 2024).

The findings of this study also reinforce Bronfenbrenner's ecological systems theory, which emphasizes the importance of the microsystem in shaping individual development. Previous research

has also shown that students' ability to persist and succeed in the learning process is influenced not only by individual abilities but also by the social support they receive from their environment (Putri, 2024). The microsystem, which includes direct interactions between students and teachers, parents, and peers, plays a crucial role in strengthening student resilience in the learning process. In this study, teachers acted as facilitators, helping students find Braille entries and scan QR codes in dictionaries, while parents provided support through home learning assistance, audio repetition, and emotional motivation. These interaction patterns indicate that student resilience not only depends on individual strengths but is also formed through social support from the immediate environment. These results align with previous research showing that supportive teacher-student relationships can enhance learning engagement and academic resilience, especially in challenging learning situations. (Roorda et al., 2011) In addition, family involvement is also known to play an important role in increasing the motivation and learning persistence of students with disabilities (Erdem & Kaya, 2020).

Although students demonstrated increased independence in using the AI-based Braille dictionary, the study also found that adult support was still needed when students encountered more complex texts or encountered technical difficulties. This suggests that the development of resilience is gradual and contextual. Contemporary resilience perspectives view resilience as a dynamic process that continuously develops through interactions between individuals and their social environment. (Ungar, 2011). Therefore, the need for support from teachers or parents does not indicate dependency, but reflects an adaptive process of negotiating resources in real learning situations.

Overall, this study makes important contributions to the study of resilience in English language learning for students with visual impairments. First, it expands the study of academic resilience in the context of learning English as a foreign language for students with visual impairments, a relatively limited area of research in Southeast Asia. Second, it demonstrates that assistive technologies such as AI-based audio Braille dictionaries can function not only as learning tools but also as protective factors that strengthen students' psychological aspects such as self-efficacy, persistence, and motivation to learn. Third, it strengthens the ecological perspective in resilience studies by demonstrating that the development of academic resilience results from the interaction between individual abilities, accessible learning technologies, and social environmental support.

Thus, resilience in English learning for blind students can be understood as the result of a dynamic interaction between personal capacity, assistive technology that supports learning accessibility, and an ecological support system involving teachers, families, and the school environment. An AI-based audio Braille dictionary acts as a crucial mediator, helping to strengthen students' self-efficacy, persistence, and learning independence, while remaining integrated within a supportive social context. Collectively, these findings indicate that resilience among blind learners is best understood as a multidimensional phenomenon involving the interaction of individual strengths, technological resources, and environmental support systems.

Building upon these findings, this study proposes a preliminary Digital Resilience Framework for blind English learners. The framework suggests that academic resilience develops through the interaction of three interconnected dimensions. The first dimension comprises internal protective factors, including persistence, self-efficacy, and adaptive problem-solving skills. The second dimension consists of technological protective resources, represented by AI-generated audio-integrated Braille dictionaries that enhance accessibility, pronunciation support, and learning autonomy. Previous studies have shown that assistive technologies play a significant role in promoting independence among individuals with visual impairments by enabling greater access to information and reducing reliance on others in daily and educational activities (Johnson, 2022). Similarly, adaptive and assistive technologies in language learning have been found to improve accessibility, learner engagement, and opportunities for autonomous English learning among students with special educational needs (Klimova, 2023). In the present study, the AI-generated audio-Braille dictionary functioned as a protective technological resource by providing multisensory access to vocabulary and pronunciation, thereby strengthening learners' confidence and independent learning behaviors. The third dimension

involves environmental protective factors, including teacher guidance, parental support, and school facilitation. The interaction among these dimensions enables learners to overcome educational barriers and maintain engagement in English learning despite visual impairments. This framework extends existing resilience literature by highlighting the role of accessible digital technologies as active protective resources in the development of resilience among students with disabilities. Through the integration of internal capacities, technological accessibility, and environmental support, resilience emerges as a dynamic process that enables blind learners to successfully adapt to educational challenges and sustain meaningful participation in English language learning.

In this framework, resilience is viewed not merely as an individual attribute but as the outcome of continuous interactions between learners, accessible technologies, and supportive ecological environments. This perspective contributes to the growing discourse on digital resilience in inclusive education and offers a conceptual foundation for future research involving learners with disabilities.

4. CONCLUSION

The conclusion of this study indicates that the use of an Artificial Intelligence (AI)-based audio Braille dictionary acts as a protective factor supporting the development of academic resilience in blind students in learning English. The results show that student resilience emerges through the interaction between individual adaptive abilities, access to easy-to-use assistive technology, and social support from their immediate environment, such as teachers and family. Students demonstrated high levels of persistence when facing difficulties in understanding English vocabulary and when experiencing technical difficulties in using the AI-based Braille dictionary. They tended to try again, find solutions, and utilize various available learning resources rather than stop the learning process. This indicates the development of a strong task orientation and adaptive problem-solving strategies in the English learning process.

Furthermore, the use of a Braille dictionary integrated with AI-based audio also improves students' self-efficacy in learning English. Students feel more confident in understanding word meanings, pronunciation, and vocabulary usage in sentences because they can access information independently through a combination of tactile and auditory experiences. This technology helps reduce students' dependence on direct teacher assistance and increases their learning independence. Within the learning environment, teacher support and parental involvement have also been shown to play a crucial role in strengthening student resilience. Teachers assist students in using dictionaries and provide guidance during the learning process, while parents accompany students while studying at home and provide emotional support. Thus, the resilience of blind students in learning English is formed through a dynamic interaction between individual factors, accessible learning technology, and social support systems within the school and family environment.

Based on the research findings, several suggestions can be put forward to improve the quality of English language learning for visually impaired students. Teachers are advised to utilize accessible learning technologies, such as AI-based Braille dictionaries, more optimally in the English learning process. Teachers are also expected to provide ongoing guidance so that students become more accustomed to using the technology independently and are able to develop more adaptive learning strategies. Furthermore, teachers can integrate the use of AI-based audio Braille dictionaries with various learning activities that involve vocabulary practice and sentence construction to develop students' language skills more comprehensively.

Schools are advised to increase the availability of learning facilities that support the needs of students with visual impairments, such as the provision of accessible technology-based learning media, disability-friendly language laboratories, and training for teachers in the use of inclusive learning technology. These efforts aim to create a more conducive learning environment and support the optimal development of the academic abilities of students with visual impairments.

Parents are advised to continue supporting their children's learning at home by assisting them with the use of AI-based Braille dictionaries and providing motivation to maintain their confidence in

learning English. Parental involvement in the learning process can help strengthen independent learning habits and increase students' persistence in overcoming learning difficulties.

Furthermore, future researchers are advised to develop broader research on the use of artificial intelligence-based technology in English language learning for students with special needs. Future research could also examine the impact of this technology on improving other language skills, such as speaking, reading, and writing, and involve a larger number of participants to provide a more comprehensive picture of the effectiveness of accessible learning technology in inclusive education.

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