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Development of Early Braille Reading Skills Teaching Module for Preschoolers: Fuzzy Delphi Method

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Abstract

The Fuzzy Delphi Method creates an early braille reading skills module for vision-impaired preschoolers. The project seeks a consensus-based, holistic solution to declining rates and technological integration in early braille literacy. Based on the Model Bottom-Up, 11 experts assessed six constructs. For analysis, FUDELO 1.0 and a 7-point Fuzzy scale were employed. Constructs provide 86% expert support for all proposed features. The study supports Sustainable Development Goal 4's inclusive education goals with evidence-based special education. Future research should focus on module adaptability, longitudinal effect studies, and practical implementation in different educational contexts and learner needs.

Keywords: Early braille reading, Fuzzy Delphi Method, preschool, visual impairment

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1.0 Introduction

Early braille literacy is crucial for blind children and it is important for them in school and in their lives (Susanti & Rudiyati, 2019). We need to teach them about touch, letters and fine motor skills, so good pre-braille activities can be done to prepare for braille (Encinas et al., 2020). We should use many senses, including touch, hearing and sight, because we use tactile games and braille story books to help learning (Alya Qasdina Ng Ai Lee et al., 2021; Polvanov, 2023). New braille technology is available, such as electronic braille boards and learning apps, but we need to use traditional methods to teach a strong braille reading foundation (Hoskin et al., 2024; Wang, 2022).

Additionally, children's progress must be monitored, therefore Fuzzy Delphi Method (FDM) was used to develop the module for early braille reading. FDM is a consensus method for experts, thus FDM is used to identify and analyze the components of the module. The study is related to the SDG 4, which is quality education and equality, and therefore various methods are needed to teach braille reading. Traditional methods, new technologies, and individual needs of children must be considered, so this study aims to develop a module which is agreed by experts.This is in the spirit of social justice and inclusive education, and thus it is essential to promote these values.

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2.0 Literature Review

Early braille literacy empowers preschoolers with visual impairments to access schooling and socialization. Traditional educational approaches emphasize tactile discrimination and fundamental word recognition (Nurul Akmal Amirah Sarudin et al., 2019; Toussaint et al., 2017). Hence, any training module should include these essential tactile competencies. Indicating that such approaches are criticized for not reaching enough cognitive and social-emotional dimensions (Cadena, 2024; Oberle & Schonert-Reichl, 2017) to increase the learning factors. These studies suggest that a well-integrated module should improve tactile abilities, mental abilities, motor coordination, and social-emotional awareness and, therefore, include assistive technologies in braille training that can be fed into module design.

Although digital tools can lead to greater engagement and personalization of learning (Saravanakumar et al., 2023), they should be integrated with traditional platforms to avoid overuse and loss of tactile proficiency (Kao & Mzimela, 2019). This has led to a balanced module design with both suitable hands-on tactile activities as well as selective technology used to enhance accessibility and motivation. The module can involve formalized tactile skills exercises, interactive technology games, and hybrid tasks to enhance braille manual reading skills.

The lack of longitudinal and contextually diverse research, as pointed out by Oberle & Schonert-Reichl (2017) and Toussaint et al. (2017), highlights the necessity to ground the module in verified empirically-based methods. The module needs to be effective while being inclusive by adapting to different kinds of learners and learning contexts, which should be prioritized at the time of design of the module (Alya Qasdina Ng Ai Lee & Kway, 2023b). The module must cover methods for personalized learning pathways, testing to monitor tactile skill development and socio-emotional learning methods for literacy education.

As a result, an early braille reading skills module should include both traditional and technology-enhanced methods while counterbalancing their limitations (Alya Qasdina Ng Ai Lee & Kway, 2023a). But that requires instruction in tactile literacy, cognitive development, socio-emotional learning as well as reasonable use of assistive technology. This program provides a foundation for visually impaired children in their early education that is evidence-based and holistic for the whole child.

2.1 Bottom-up Model

The Bottom-Up Model in early braille literacy emphasizes a sequential approach, starting with basic tactile and perceptual skills before advancing to more complex literacy tasks. This model illustrates the need for tactile discrimination, where children differentiate braille characters based on the positioning of their dot configuration. Models of literacy development emphasize the role of foundational skills as building blocks for advanced literacy development, and research such as that by Alya Qasdina Ng Ai Lee et al. (2021) reveal proficiency in tactile discrimination is robustly predictive of young children who can read braille successfully.

However, the Bottom-Up Model has faced criticism for its narrow focus, with scholars arguing that it overlooks the role of cognitive and socio-emotional factors in reading development. For example, studies by Yet research on the Bottom-Up Model have been criticized for its analytic scope – scholars argued that the model does not consider cognitive and socio-emotional facets that play important roles in reading development. UNESCO (2024) promote a more holistic approach, specifically the integration of emotional and social learning as a means of achieving literacy-loan outcomes. This critique speaks to the danger of separating tactile talents from the bigger purpose of learning.

It is important to note the Bottom-Up Model does have limitations to consider. However, it still serves as a valuable framework for structuring braille instruction, especially with respect to the systematic progression through skills. It needs to be fortified with strategies that include cognitive and social aspects of braille literacy development so it can improve on its deficits. The data of this literature review indicates the importance of structured and individualized teaching of braille literacy skills to preschoolers, including the need for comprehensive braille literacy teaching methods for very young children. Hence, this research aims to describe and develop the main constructs of early braille reading skills modules for preschoolers based on expert consensus.

3.0 Methodology

This research is conducted using the Multi Research Method (Richey & Klein, 2007) based on Design and Development Research (DDR) and this research involved two stages, the first stage is a literature review to obtain the main variables of teaching early braille reading. The second stage is using the FDM to reach an agreement of experts on the main variables of teaching early braille reading because FDM is a modified Delphi method using fuzzy logic to make expert judgment more accurate and synthesis different opinions. The iterative process of FDM involves several rounds of expert feedback which are analyzed using quantitative and qualitative methods to ensure that the main variables of teaching early braille reading are clearly defined and agreed upon before data analysis, thus a consensus evaluation tool is applied in the FDM process to rank and finalize the main variables, ensuring that they are clearly defined and agreed upon before data analysis. This process not only strengthens the validity and reliability of the research but also ensures alignment with the study's objectives by combining insights from literature and expert consensus, therefore it is a crucial step in the research methodology.

3.1 Sampling procedure

This analysis utilizes purposeful sampling, as it is well-suited for obtaining expert agreement on predetermined topics. Hasson et al. (2000) highlight purposeful sampling as the most appropriate approach for the FDM. In this study, 11 experts participated, as detailed in Table 1. These experts were selected based on their qualifications and expertise. According to Clayton (1997), if all specialists share the same background, the recommended number of experts ranges from 5 to 10. However, maintaining consistency typically requires a minimum of 10 to 15 experts for a Delphi study (Adler & Ziglio, 1996).

Table 1: List of experts

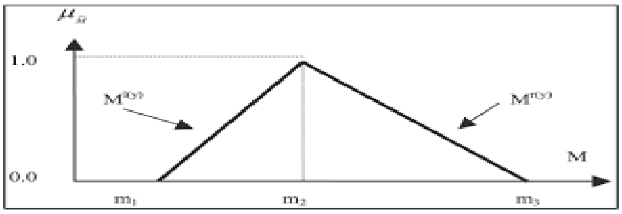
Expert	Field of expertise	Institution
2 Lecturer	Visual Impairment	Institute Of Teacher Education
2 Officer		Ministry of Education Malaysia
3 Preschool Teachers		Public School
4 Special Education Teachers		Public School

3.2 Expert criteria

As per Booker and McNamara (2004), experts are individuals who possess specialized knowledge and skills in a specific area. They earn their status through rigorous qualifications, extensive training, practical experience, professional affiliations, and recognition by their peers (Cantrill, Sibbald, & Buetow, 1996; Mullen, 2003). In FDM research, the selection of experts plays a pivotal role. Inadequate expert selection can undermine the credibility, validity, and reliability of the study (Mustapha & Darusalam, 2017). According to Kaynak and Macauley (1984), researchers must ensure that experts possess sufficient knowledge of the subject matter. Following strict criteria, the researcher selects specialists who have at least seven years of experience and relevant knowledge for the study.

3.3 Fuzzy Delphi Step

Table 2: FDM step

Step		Formulation
1.	**Expert Selection**	11 professionals contributed to this paper. A team of specialists assessed the impact of the assessment parameters on linguistic variables. Define potential piece issues, etc.
2.	**Determining linguistic scale**	Translation of all linguistic variables into Fuzzy triangle counting is required. Fuzzy numbers are added to linguistic variable translations (Hsieh, Lu and Tzeng, 2004). Written as (m1, m2, m3), the Triangular Fuzzy Number represents m1, m2, and m3. The lowest value is m1, the rational value is m2, and the highest value is m3. In contrast, the triangular fuzzy number generates a fuzzy scale that transforms linguistic variables into fuzzy numbers.  Figure 1: Triangular Fuzzy Number
3.	**The Determination of Linguistic Variables and Average Responses**	After consulting the expert, the researcher must convert all measurement results to Fuzzy scales. This generally acknowledges each solution (Benitez, Martin & Roman, 2007).
4.	**The determination of threshold value "d"**	Expert agreement depends on the threshold value (Thomaidis, Nikitakos & Dounias, 2006). Distances for Fuzzy integers m = (m1, m2, m3) and n = (m1, m2, m3) are calculated using the formula: $d(\bar{m},\bar{n}) = \sqrt{\frac{1}{3}\left[(m1-n1)^2 + (m2-n2)^2 + (m3-n3)^2\right]}$
5.	**Identify the alpha-cut aggregate level of the Fuzzy assessment**	Each piece receives a Fuzzy Number if experts agree (Mustapha & Darussalam, 2017). The Fuzzy value calculation and measurement method is: 1/4*(m1+2m2+m3) Amax
6.	**Defuzzification process**	This technique use the formula Amax = 1⁄4* (a1 + 2am + a3). Researchers can utilize Average Fuzzy Numbers or average responses to calculate a score between 0 and 1 (Mohd Ridhuan Mohd. Jamil & Nurulrabihah Mat Noh, 2021). Three formulas are used in this process: A = 1/3 * (m1 + m2 + m3), 1/4 * (m1 + 2m2 + m3), or 1/6 * (m1 + 4m2 + m3). A-cut value equals the median of '0' and '1', with α-cut = 0.5 ((0 + 1) / 2). If the A value falls below the α-cut value of 0.5, the item is rejected as it does not reflect expert agreement. Bojdanova (2006) recommends alpha cut values above 0.5. Tang and Wu (2010) recommend an α-cut value greater than 0.5.
7.	**Ranking process**	The placement method defines elements based on defuzzification values and expert agreement that the most significant element is an essential decision place (Fortemps & Roubens, 1996).

3.4 Instrumentation

The researcher developed the FDM research tool using insights from relevant literature. Questionnaire items can be informed by literature reviews, pilot studies, as well as practical experience (Skulmowski, Hartman, & Krahn, 2007). Thus, they employed research literature, expert interviews, and focus groups to generate FDM questions (Mustapha & Darussalam, 2017). A literature review should precede study items and content development, according to Okoli and Pawlowski (2004).

Researchers used published work/literature to determine the key constructs in the early braille reading skills module. An expert question list is then formed employing a 7-point scale. A 7-point scale was chosen as it provides greater precision as well as excellent results (Chang et al., 2011). The researcher substituted the Fuzzy value in Table 4 with a 1–7 scale value to simplify professional questionnaire responses:

Table 3: Fuzzy scale

Item	Fuzzy Number
Strongly disagree	(0.0, 0.0, 0.1)
Disagree	(0.0, 0.1, 0.3)
Somewhat Disagree	(0.1, 0.3, 0.5)
Neutral	(0,3, 0.5, 0.7)
Somewhat agree	(0.5, 0.7, 0.9)
Agree	(0.7, 0.9, 1.0
Strongly agree	(0.9, 1.0, 1.0)

3.5 Data Analysis

The researcher used FDM Logic Software (FUDELO 1.0) to look at the results of this study. This software was made to look at FDM data (Mustapha et al., 2024).

4.0 Findings

This section presents expert consensus on early braille reading skills module structures. 11 relevant experts were asked Fuzzy Delphi questions, and their responses were used to collect data. Table 4 shows the threshold value.

Table 4: Threshold value

Results	Item 1	Item 2	Item 3	Item 4	Item 5	Item 6
Expert 1	0.049	0.049	0.049	0.049	0.049	0.049
Expert 2	0.049	0.049	0.049	0.049	0.049	0.049
Expert 3	0.049	0.049	0.049	0.049	0.049	0.049
Expert 4	0.049	0.049	0.049	0.049	0.049	0.106
Expert 5	0.049	0.049	0.049	0.049	0.106	0.049
Expert 6	0.049	0.049	0.049	0.106	0.049	0.049
Expert 7	0.106	0.106	0.106	0.049	0.049	0.049
Expert 8	0.049	0.049	0.049	0.049	0.049	0.049
Expert 9	0.049	0.049	0.049	0.049	0.049	0.049
Expert 10	0.049	0.049	0.049	0.049	0.049	0.049
Expert 11	0.343	0.343	0.343	0.343	0.343	0.343

Table 4 presents a comprehensive overview of threshold values for 11 experts across six items. The data reveals a striking consistency among 8 of the 11 experts, who maintain a threshold value of 0.049 across all items, indicating a high degree of inter-rater reliability. However, the table also highlights some notable variations. Experts 4, 5, and 6 each exhibit a single item with an elevated threshold of 0.106, while Expert 7 demonstrates this higher value for the first three items. Most notably, Expert 11 presents as a significant outlier, with a consistently higher threshold of 0.343 across all items. These variations introduce an element of heterogeneity to the overall consensus, providing a nuanced perspective on the expert evaluations.

Table 5: Overall result

Statistics	Item 1	Item 2	Item 3	Item 4	Item 5	Item 6
Value of the item	0.081	0.081	0.081	0.081	0.081	0.081
Value of the 'd' construct	0.081	0.081	0.081	0.081	0.081	0.081
Item < 0.2	6	6	6	6	6	6
% of item < 0.2	86%	86%	86%	86%	86%	86%
Average of % consensus Defuzzification	0.933	0.933	0.933	0.933	0.933	0.933
Ranking	1	1	1	1	1	1
Status	Accept	Accept	Accept	Accept	Accept	Accept

Table 5 offers a compelling summary of the overall results, revealing several key findings. The uniformity of item values at 0.081, including the 'd' construct value, suggests a robust and internally consistent construct. Notably, all items fall below the 0.2 threshold, typically indicative of strong agreement, with an impressive 86% consensus rate for each item. The average consensus defuzzification value of 0.933 is remarkably high, signifying an exceptionally strong convergence of expert opinions. Furthermore, the uniform ranking of 1 and 'Accept' status across all items underscores the unanimous endorsement of the construct under study. These results collectively suggest a high degree of construct validity and inter-rater reliability, offering a robust basis for further analysis as well as interpretation within the research context.

These results suggest that all proposed items are relevant and important for the study, with strong expert consensus. Figure 1 shows the main constructs for the early braille reading skills module that have reached expert consensus through the FDM.

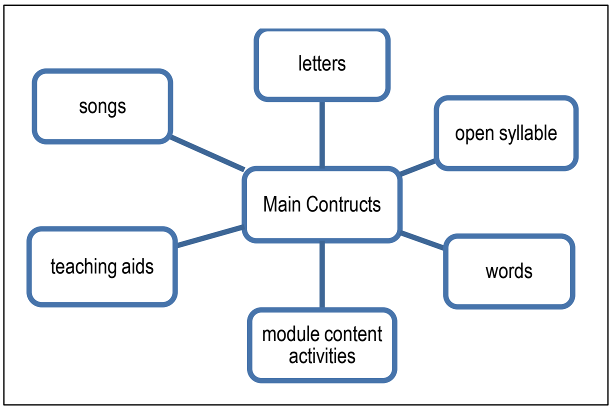


Fig. 1: Main constructs

5.0 Discussion

The FDM employed in this study has yielded compelling results regarding the consensus on early braille reading skills module structures. The findings, as presented in Tables 4 and 5, demonstrate a high level of agreement among experts, which has significant implications for the field of special education for the visually impaired. The remarkably consistent threshold value of 0.049 across 8 of the 11 experts for all items (Table 4) indicates a strong inter-rater reliability. This level of agreement aligns with previous studies utilizing FDM in educational research. For instance, Chang et al. (2011) noted that such consistency often signifies a well-designed construct and clear item formulation. The overall results (Table 5) further solidify the construct validity of the proposed early braille reading skills module. With all items falling below the 0.2 threshold and an impressive 86% consensus rate, these findings echo the work of Hsu and Chen (1996), who established that consensus rates above 75% in FDM studies indicate strong construct validity.

The presence of outliers, particularly Expert 11 with consistently higher threshold values, merits discussion. While outliers can sometimes be viewed as problematic, in Delphi studies, they often provide valuable insights. As pointed out by Okoli and Pawlowski (2004), divergent opinions in expert panels can highlight areas for further investigation or refinement in the construct. Notably, the average consensus defuzzification value is as high as 0.933. According to Ragin (2008), defuzzification scores above 0.9 reflect an exceptionally strong agreement among experts. This high value indicates that the expert panel did not only accept but strongly endorse the proposed constructs for the early braille reading skills module.

Such a universal reception of items in the construct has major ramifications for braille literacy instruction. This aligns with the growing number of studies that emphasize the value of structured, expert-validated methods in beginning braille education. For instance, the study carried out by Koenig and Holbrook (2000) emphasized that properly structured braille literacy programs have the potential to vastly enhance the reading success of visually impaired children. The fact that this study relied on FDM can be seen as a methodological strong point of the study, as it preserves the advantages of classic Delphi methods and adds additional accuracy via Fuzzy set theory (Ishikawa et al., 1993). On the other hand, although FDM gives solid quantitative data, it means the qualitative manner of the experts' opinions is left behind. A mixed-methods approach, as advocated by Hasson and Keeney (2011), might also be valuable for future studies so that insights can be provided into the rationales of the experts.

This strong consensus sets the stage for future studies. Future areas of study may include longitudinal studies to measure the efficacy of the validated module structures in practice in actual educational settings, studies comparing traditional versus newly validated braille instruction methods, and exploration of how the module structures may be modified for use with different aged children or those with multiple disabilities. An early braille reading skills module was successfully validated in this study using the FMD. Expert consensus is a powerful mechanism for assuring the establishment of structured braille literacy programs or enhancing existing ones. Demonstrating efficacy through evidence-based methods will be pivotal for the future of special education programming as a whole and ultimately help us come up with the optimal programming for our learners with visual impairments.

6.0 Conclusion and Recommendations

A braille learning module for visually impaired preschool children was developed and the level of agreement on the development of the braille learning module for deafblind preschool children was 86%. The defuzzification value for the level of agreement on the development of the braille learning module for deafblind preschool children is between 0.914 and 0.929, therefore the findings are congruent with previous research findings (Martiniello et al., 2018). This study utilized expert judgements as well as literature review, thus one of the experts disagreed, which indicated that there were many views that were different from the opinions of the experts. This is similar to the findings of Alya Qasdina Ng Ai Lee & Kway (2023a), so there are some limitations in the study. 2) Limited number of experts involved, and 3) uses number data only (agreement), because 4) has not been trialled in schools. Future studies should involve more experts with varied backgrounds; both number and word data; and the module should be trialled in schools to see how effective it is, therefore experts should also consider the use of technology to assist, and how to adapt the module to individual children. Teachers should also be trained on how to use the module, because they need more information on how to adapt it to different contexts. Parents should be included to teach braille in early stages, thus researchers should also explore the use of multisensory learning and the means of obtaining feedback from experts to further improve the module. This module is an attempt to teach visually impaired preschoolers, and the module was developed by early childhood, special education and Bahasa Melayu experts, so it is designed to teach braille to visually impaired children.

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Paper Contribution to Related Field of Study

This project fills a key need in braille reading education for visually challenged students. The FDM is used to discover and validate the essential structures of an early braille reading skills module. This study lays the groundwork for future research and applications by achieving expert consensus on these constructs. The findings provide significant insights for examining new components, exploring alternative sample populations, and building unique models or modules to improve early braille literacy training. This report adds preliminary but significant data to special education research, notably braille literacy. While readers may critique the technique or logic, the paper clearly states its objective, findings, and potential influence on the area. The study provides a verified paradigm for braille literacy education practices, curriculum, and policy. The authors have reported no conflicts of interest, ensuring research integrity. This study helps educators, researchers, and policymakers enhance educational results for visually impaired students.

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