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Arithmetic: A Learning Aid Tool for Year 1 Mathematic (Hearing-Impaired Students)

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ABSTRACT

Effective educational interventions are critical in narrowing learning disparities among hearing-impaired children, a particularly pressing issue in nations such as Malaysia. This study focuses on hearing-impaired students' challenges in STEM subjects, primarily mathematics. The objective is to develop and evaluate the ARithmetic application, an augmented reality (AR)-based learning aid designed to teach Year 1 mathematics to hearing-impaired students. Guided by the Multimedia Development Life Cycle (MDLC), the research incorporated AR technology to create an interactive and accessible learning environment. A quantitative approach was employed using questionnaires, and the responses were analyzed with SPSS 26.0 through descriptive statistics. The results demonstrate consistently high mean scores across all dimensions: perceived usefulness (M = 4.21), perceived ease of use (M = 4.06), perceived enjoyment (M = 4.25), attitude towards use (M = 4.19), and intention to use (M = 4.26), indicating strong user acceptance. Reliability was confirmed with Cronbach's alpha (α = 0.821). These findings validate the ARithmetic application as a reliable and engaging tool that fosters accessibility and enjoyment in mathematics learning for hearing-impaired students. Overall, the study highlights the potential of AR technology to support inclusive education and bridge learning gaps in STEM subjects.

1. Introduction

The World Health Organization (WHO) has recently assessed over 34 million children worldwide and found that hearing loss predominantly affects those from low-to-middle-income countries. In Malaysia, the prevalence of hearing loss in children varies significantly by age group: 3.5% of teens aged 13-17 years old, 6.6% of children aged 7-12 years old, and 6.6% of toddlers and small children

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aged 3-6 years old have hearing loss [1]. These statistics are alarming because most hearing loss is preventable with early detection and appropriate intervention.

Children with hearing impairment often encounter delays in speech and language development, social isolation, poor educational performance, and behavioral issues. These difficulties extend to communication challenges with family members, friends, and peers, which can lead to anxiety, depression, and frustration [1]. Addressing these issues requires a comprehensive approach to early detection, intervention, and support to mitigate the adverse effects of hearing loss on children's overall development and well-being. According to the Malaysian Education Blueprint 2013-2025 (Preschool to Post-Secondary Education), specifically under Shift 1, there is a clear emphasis on ensuring equitable access to high-quality education of international standards. It includes individuals with disabilities, as the goal is to ensure that no one is left behind in receiving quality educational opportunities [2]. Unfortunately, the official government Inclusive Education Program, including special schools and Special Education Integration Program settings, educates only 1% of deaf children. Deaf children in mainstream schools are not formally registered, making it currently unknown if there are more or fewer unidentified deaf children enrolled in mainstream schools [3]. This lack of formal registration highlights a significant gap in identifying and supporting deaf children within the mainstream education system.

STEM (Science, Technology, Engineering, and Mathematics) subjects form the foundation for many critical skills in today's world. However, students with hearing impairments often face unique challenges in mastering these subjects, particularly mathematics. The traditional classroom environment and teaching methods may not adequately address their specific needs, leading to a significant gap in their STEM education. Year 1 hearing-impaired students use the same textbooks as those without hearing impairments, exacerbating their difficulties due to the lack of tailored content. Students with hearing impairments are struggling with STEM subjects, especially mathematics, due to the lack of effective learning aids tailored to their needs. In mathematics classes for students with hearing impairments, teachers frequently face challenges in locating ready-made materials that align with the instructional content as well as the language, cognitive, and readiness levels of these students [4]. As a result, teachers often need to create their own instructional materials tailored to the needs of hearing-impaired students [5]. Conventional educational tools and methods do not cater to their auditory challenges, resulting in difficulties in understanding and retaining mathematical concepts. This not only hampers their academic performance but also limits their future opportunities in STEM-related fields.

The objectives of this research are as follows: Firstly, it aims to identify sign language content explicitly tailored for Year 1 Mathematics to cater to students with hearing impairments. Secondly, the study endeavors to develop an application focusing on selected topics within the Year 1 Mathematics curriculum tailored to the unique needs of hearing-impaired students. Lastly, the research intends to evaluate the effectiveness of the developed application through pre-test and post-test evaluations. In terms of scope, this research encompasses the development of the ARithmetic application. This application meticulously aligns with the Year 1 Mathematics syllabus stipulated by the Ministry of Education Malaysia. It will comprehensively cover essential topics such as numbers, operations, days, and shapes. This targeted approach ensures that the content directly correlates with the curriculum, effectively fulfilling the educational requirements of Year 1 students with hearing impairments.

2. Related Work

In recent years, the education of hearing-impaired students has emerged as a topic of increasing importance within educational research. Despite advancements in technology and pedagogy, these students face unique challenges, particularly in subjects requiring abstract reasoning and conceptual understanding, such as mathematics. Understanding the current landscape of research in this field is crucial for identifying gaps and opportunities to enhance the educational experiences of hearing-impaired students.

The education of hearing-impaired students presents unique challenges, particularly in subjects requiring a solid grasp of abstract concepts, such as mathematics. Despite advancements in educational technology and pedagogy, there remains a significant gap in resources designed to support hearing-impaired students in STEM education. In Malaysia, although Bahasa Isyarat Malaysia (BIM) is the official language of the deaf community, hearing-impaired students typically use Kod Tangan Bahasa Malaysia (KTBM) for learning. KTBM, currently the only form of sign language recognized by the Ministry of Education, is used to teach in formal education settings [6] . To overcome these obstacles, mobile applications, with their interactive and personalized learning elements, offer a promising solution by providing individualized educational experiences that cater to the unique needs of these students [7]. Table 1 explores the current state of educational tools and methods for teaching mathematics to hearing-impaired students, examining the limitations of existing materials and the potential benefits of specialized learning aids.

Table 1
Pros and cons of the current applications

Applications	Pros	Cons
Malaysian Sign Language Mobile Learning [8]	• It provides a sign detention module allowing users to capture images of signs using their phone camera to detect sign language labels in the image. • Offers learning by category, enabling users to learn different types of signs efficiently.	• The app's color selection is not attractive. • The interface is not suitable for children. • The interface of the application is boring.
KoTBaM [9]	• Includes sign language in sentences that represent actual conversations or situations. • Provides category-based learning, facilitating users' effective learning of various sign categories.	• It does not have a quiz and is solely for learning sign language.
KTBM AR [10]	• Offers various interactive activities that aid the learning process with short-answer questions or filling in the blanks with the correct answers. • Gives quiz functionality to test users' knowledge.	• The interface is too concise. • The interface is not user friendly.
Bimo AR [11]	• Utilizes 3D models with animations to illustrate sign language gestures • Provides search by index functionality	• The interface is dull and too simple.

The comparison of features, including Operating System, Language, User, Application Interface, Augmented Reality, and Quiz, between the applications is detailed in Table 2 below.

Table 2
A comparison of features between current application

Features	Malaysian Sign Language Mobile Learning	KoTBaM	KTBM AR	BImo AR
Operating System	Android	Android	Android	iOS
Language	Malay	Malay	Malay	Malay/English
User	Hearing Impairment	Teachers	Hearing Impairment	Hearing Impairment
Interface	Cheerful	Cheerful	Cheerful	Cheerful
Augmented Reality	Yes	No	Yes	Yes
Quiz	No	No	Yes	Yes

Based on Table 2, all the applications run on Android except for Bimo AR, which operates on iOS. This platform difference is significant as it impacts the accessibility and availability of the app for users on different devices. Regarding language support, Bimo AR offers both English and Malay, catering to a broader audience and enhancing usability for bilingual users. In contrast, the other applications provide support only in Malay, which may limit their accessibility to non-Malay-speaking users. The target audience varies for each app; most applications specifically target hearing-impaired students, whereas KoTBaM targets teachers. All the applications boast cheerful interfaces characterized by bright colors, engaging visuals, and user-friendly navigation, which can enhance user engagement and learning experience. However, KoTBaM lacks augmented reality (AR) features, which is a significant omission considering that AR can provide interactive and immersive learning experiences that benefit students by visualizing complex concepts. Finally, including quizzes, while most applications incorporate quizzes to reinforce learning and assess comprehension, Malaysian Sign Language Mobile Learning and KoTBaM lack this element. The absence of quizzes in these apps could be a drawback, as quizzes are practical tools for reinforcing learning and providing immediate feedback to students.

3. Methodology

The methodology for this research follows the Multimedia Development Life Cycle (MDLC) [12] (refer to Figure 1), a comprehensive framework designed for developing multimedia applications. The MDLC was chosen due to its structured approach, which ensures systematic multimedia project planning, development, and evaluation. This methodology is particularly suitable for developing educational applications, as it emphasizes iterative testing and user feedback to refine the product.

3.1 Concept

The ARithmetic application systematically develops a visually engaging and accessible learning platform for hearing-impaired students. Utilizing AR technology offers interactive and immersive learning experiences that enhance comprehension for these students. ARithmetic is aligned with Sustainable Development Goal 4 (SDG 4), which strives for inclusive and equitable quality education. By providing educational support tailored to the needs of hearing-impaired students, ARithmetic contributes to the global objective of inclusive education and equal opportunities for all learners.

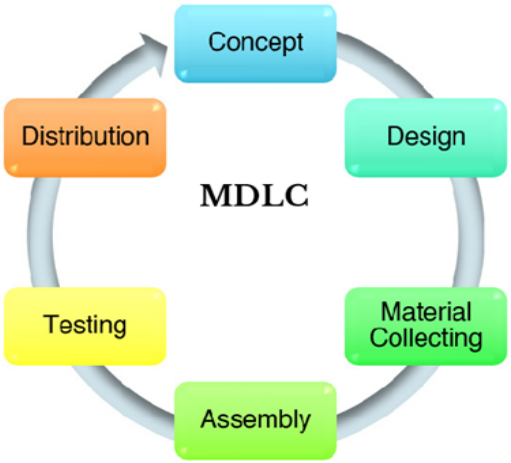


Fig. 1. Methodology Development Life Cycle (MDLC) Model

3.2 Design

The design phase of the ARithmetic application focuses on creating an engaging and accessible learning platform for hearing-impaired Year 1 students in Mathematics. This phase begins with storyboarding and wireframing to outline the sequence of interactions and the user interfaces (UI) structure. The visual design is crafted to be appealing and includes high-contrast visuals and sign language animations to enhance accessibility. Interactive elements like 3D models and simulations are planned to provide immersive learning experiences. The content design ensures that mathematical topics are effectively presented using AR technology, with sign language integrated for clear communication. This comprehensive design approach aims to deliver a user-friendly and effective educational tool.

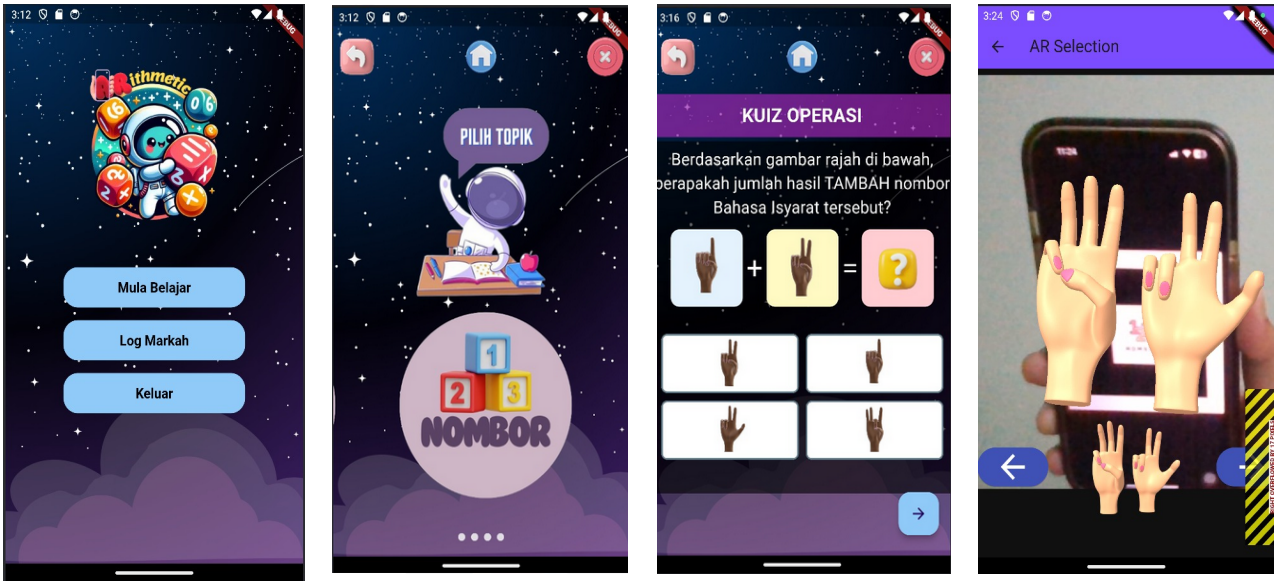
3.3 Material Collecting

ARithmetic is developed using multiple software tools. One of the main tools is IntelliJ IDEA, an Integrated Development Environment (IDE) used for writing and managing code. The ARithmetic interface is built with Flutter, which utilizes the Dart language. Quiz marks and module videos are stored in Firebase, a cloud-hosted NoSQL database. The AR framework is implemented using HTML. Blender is used to create and design three-dimensional objects, and Canva is employed to design buttons and graphics, enhancing the visual appeal of the interface.

3.4 Assembly

IntelliJ IDEA was chosen as one of the leading software tools for developing ARithmetic because it offers comprehensive support for Flutter development. Flutter, a high-performance cross-platform framework created by Google, uses the Dart programming language [13]. Dart is an object-oriented language that supports concepts like classes and interfaces. It follows a single codebase approach, allowing developers to write code once and deploy it across iOS, Android, web, and desktop platforms. This approach ensures consistency, reduces development costs, shortens testing times, and boosts productivity. The firebase was selected for database storage because it handles data in JavaScript Object Notation (JSON) format, eliminating the need for manual data insertion, updating, deletion, or addition. Firebase provides real-time database and backend services, with an API that

synchronizes application data across clients and stores it on Firebase's cloud [14]. Figure 2 shows some of the interfaces of ARithmetic.



(a) (b) (c) (d)

Fig. 2. ARithmetic interfaces (a) Main Menu (b)Topic (c) Quiz (d) AR Mode

3.5 Testing

The testing phase was conducted to assess the overall effectiveness and user experience of the ARithmetic application. Specifically, this evaluation focused on five key aspects: usefulness, ease of use, enjoyment, user attitude, and intention to use. This phase played a critical role in determining how well the app meets the learning needs of Year 1 students with hearing impairments while examining its technical performance and usability. Feedback was gathered from diverse stakeholders, including educators, parents, and subject-matter experts in augmented reality (AR) and mobile app development. Their perspectives helped ensure a well-rounded evaluation of the app's educational value and technological functionality. The following subsections describe the sampling techniques, research instruments, and evaluation procedures used during this testing phase.

3.5.1 Sampling

The study involved three distinct groups of participants: special education teachers specializing in sign language, parents of children who are deaf or hard of hearing, and experts in augmented reality (AR) and app development. The research was conducted across two schools in Johor, Kluang and Batu Pahat. Prior to the commencement of the study, informed consent was obtained from the respective schools. A total of 25 respondents, all directly involved with hearing-impaired children, participated in testing the ARithmetic application. These participants were given a detailed briefing on the app's background and a live demonstration of its features and functionalities. This step was essential to ensure that all respondents clearly understood how the app works before providing feedback through a structured Google Form. Table 3 presents the demographic details of the respondents. The feedback gathered from these key stakeholders is critical in evaluating whether the ARithmetic application effectively addresses the learning needs of students with hearing impairments, particularly in enhancing their understanding and engagement in mathematics.

Table 3
Demographic information

Demographic	Variables	Frequency	Percentage (%)
Gender	Male	10	40.0
	Female	15	60.0
Role	Teachers	16	64.0
	Parents	7	28.0
	Expert in AR and app	2	8.0

3.5.2 Instrument

A questionnaire was developed to evaluate users' acceptance of the ARithmetic application, aligning with the framework used in previous studies [15]. The instrument consists of fourteen items grouped into five key dimensions: perceived usefulness, perceived ease of use, perceived enjoyment, attitude towards use, and intention to use. These dimensions, as detailed in Table 4, provide a comprehensive overview of users' experiences and acceptance of the technology.

Table 4
Dimensions and components of the survey instrument

Component	Item	Statement
Perceived Usefulness (PU)	PU1	The ARithmetic app helps students with hearing impairments understand mathematics concepts better.
	PU2	The content provided in the app is relevant to the students' learning needs.
	PU3	The app supports my teaching/parental role effectively.
	PU4	The app improves students' engagement in learning mathematics.
	PU5	I believe this app can contribute positively to academic performance.
Perceived Ease of Use (PEU)	PEU1	The app is easy to navigate and use, even for first-time users.
	PEU2	Instructions and prompts within the app are clear and understandable.
	PEU3	It is easy to access the AR features in the app.
	PEU4	I did not encounter major difficulties while using the app.
	PEU5	The app runs smoothly without technical issues.
Perceived Enjoyment (PE)	PE1	The use of Augmented Reality (AR) makes the learning experience more enjoyable.
	PE2	Students seemed excited while interacting with the app.
	PE3	The design and animations are fun and engaging.
	PE4	The activities in the app are entertaining while still educational.
	PE5	I would enjoy using this app frequently in learning/teaching sessions.
Attitude towards its Use (AU)	AU1	I find the ARithmetic app to be a valuable educational tool.
	AU2	I have a positive overall impression of the app.
	AU3	I believe that using AR in education is a good approach.
	AU4	The app makes learning more interactive.
	AU5	The students can learn from the app on their own with minimal guidance.

Table 4 (*Continued*)
Dimensions and components of the survey instrument

Component	Item	Statement
Intention of Use (IU)	IU1	I plan to continue using the ARithmetic app in the future.
	IU2	I am willing to integrate this app regularly in my teaching or child's learning routine.
	IU3	I would like to see this app implemented in school settings.
	IU4	I would recommend this app to deaf and hard-of-hearing students.
	IU5	This app is preferable compared to other learning tools.

The questionnaire responses were analyzed using a Likert scale [16], as shown in Table 5, to quantitatively assess the extent to which the research objectives were met.

Table 5
Likert scale

Rating	Scale
Completely disagree	1
Disagree	2
Neutral	3
Agree	4
Completely agree	5

The instrument's reliability was evaluated using Cronbach's alpha coefficient, a widely accepted measure of internal consistency. This statistic reflects how closely related the items within each dimension of the questionnaire are, indicating how reliably they assess the same underlying construction. As George and Mallery [17] suggested, Cronbach's alpha value of 0.7 or above is typically considered acceptable for social science research. Following this benchmark, Table 6 presents the Cronbach's alpha values for each instrument dimension, demonstrating the reliability of the questionnaire used in this study.

Table 6
Range of reliability and its coefficient of Cronbach's alpha

Cronbach Alpha Value	Category
More than 0.90	Excellent
0.80 – 0.89	Good
0.70 – 0.79	Acceptable
0.60 – 0.69	Questionable
0.50 – 0.59	Poor
Less than 0.50	Unacceptable

The collected data were analyzed using the Statistical Package for the Social Sciences (SPSS) software version 26.0. This study employed quantitative analysis techniques, focusing on descriptive statistics to examine key dimensions such as perceived usefulness, perceived ease of use, perceived enjoyment, user attitude, and intention to use. Mean scores were calculated from the questionnaire responses, which were measured using a Likert scale, to capture participants' levels of agreement. To facilitate interpretation, the mean scores were categorized into three levels, i.e., low, medium, and high acceptance, as shown in Table 7, following the guidelines outlined by Yusof *et al*., [18].

Table 7
Mean range level interpretation

Mean Score Range	Interpretation
1.00 – 2.32	Low
2.33 – 3.65	Moderate
3.66 and above	High

3.6 Distribution

The ARithmetic application has officially launched on the Google Play Store. This innovative educational tool enhances basic mathematics skills, particularly benefiting students with hearing impairments. ARithmetic is freely accessible to everyone, eliminating financial barriers and ensuring that quality educational resources are available to a broader audience.

4. Result and Discussion

The data collected from the study offered meaningful insights into how participants perceived the ARithmetic application. Using quantitative analysis and descriptive statistics, this section highlights findings derived from the responses of teachers, parents, and experts. Key dimensions explored include perceived usefulness, ease of use, enjoyment, and overall attitude toward the app. Each dimension is discussed to show how different user groups engaged with the app clearly and evaluated it, as summarized in Table 8.

Table 8
Mean values, standard deviation and level of the instrument

Dimension	Item	Mean	Std. Deviation	Level
Perceive Usefulness (PU)	PU1	3.96	0.789	High
	PU2	4.2	0.707	High
	PU3	4.08	0.640	High
	PU4	4.4	0.577	High
	PU5	4.24	0.779	High
Perceived Ease of Use (PEU)	PEU1	4.24	0.779	High
	PEU2	3.92	0.759	High
	PEU3	4	0.707	High
	PEU4	3.88	0.781	High
	PEU5	4.28	0.792	High
Perceived Enjoyment (PE)	PE1	4.48	0.770	High
	PE2	4.36	0.757	High
	PE3	4.12	0.725	High
	PE4	4.08	0.759	High
	PE5	4.2	0.763	High
Attitude towards its Use (AU)	AU1	4.2	0.763	High
	AU2	4.28	0.737	High
	AU3	4.24	0.663	High
	AU4	4	0.763	High
	AU5	4.24	0.663	High
Intention of Use (IU)	IU1	4.28	0.737	High
	IU2	4.32	0.802	High
	IU3	4.16	0.746	High
	IU4	4.12	0.725	High
	IU5	4.4	0.645	High

Table 8 presents the descriptive statistics of the instrument used in the study, covering five key dimensions: Perceived Usefulness (PU), Perceived Ease of Use (PEU), Perceived Enjoyment (PE), Attitude towards Use (AU), and Intention of Use (IU). Across all dimensions, the mean values range from 3.88 to 4.48, indicating consistently high levels of agreement among respondents, as all items fall within the "High" level category. The highest mean (M = 4.48) was recorded for PE1 under the Perceived Enjoyment dimension, suggesting that users found the system highly enjoyable. Similarly, strong scores were observed in Intention of Use (IU), with IU2 (M = 4.32) and IU5 (M = 4.40) reflecting positive intentions to continue using the system. Although PEU4 scored slightly lower (M = 3.88), it still reflects a high perceived ease of use, suggesting minimal usability concerns. The standard deviations, ranging from 0.577 to 0.802, are relatively low, indicating a reasonable consistency in participants' responses. Overall, the instrument demonstrates strong user acceptance and satisfaction across all measured constructs and suggests that the target users both find the app user-friendly and favorably perceive the system.

5. Conclusion

In conclusion, ARithmetic represents an innovative learning tool that effectively teaches fundamental mathematics concepts to students with hearing impairments, aligning with the needs of inclusive education in today's digital era. Developed using the Multimedia Development Life Cycle (MDLC) and tested with real users, including teachers, parents, and subject matter experts, the app integrates Augmented Reality to create an engaging, accessible, and interactive learning environment. Findings from the usability study revealed high levels of perceived usefulness, ease of use, enjoyment, and intention to use, highlighting its effectiveness and acceptance among the target audience. Beyond enhancing comprehension and enjoyment of mathematical learning, ARithmetic is vital in promoting educational equity by addressing the unique needs of hearing-impaired learners. By merging contemporary technology with traditional pedagogy, this research contributes to the body of knowledge in special needs education. It demonstrates a practical application that can be scaled and adapted for broader educational use. Ultimately, ARithmetic empowers hearing-impaired students to master foundational math skills essential for academic achievement and everyday life.

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