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Research Article:

Design of Augmented Reality Elements for a Primary School Reading Module

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ABSTRACT

Reading skills serve as a foundational pillar in early primary education, particularly in fostering literacy and holistic cognitive development. However, conventional pedagogical methods often fail to capture pupils' attention and sustain their engagement in reading activities. Addressing this challenge, the present study aims to develop a reading module enhanced with Augmented Reality (AR) elements to improve the effectiveness and engagement of pupils in the learning process. The module was developed using the Design, Develop, and Research (DDR) model, which comprises three main phases: needs analysis, design and development, and evaluation. This article focuses specifically on the design phase. A total of 21 experts participated in the study, and data were collected using a checklist instrument and analysed using the Fuzzy Delphi Method (FDM) to obtain expert consensus across diverse backgrounds in education and AR technology. The module and AR elements were developed using Buildbox Classic, Makar App, and Adobe Illustrator. The AR features included interactive 3D visualisations of vowels, consonants and syllables, voiced animations, and a user-friendly interface that supports self-directed learning. Preliminary findings indicated that the AR elements enhanced pupils' interest, improved their focus, and facilitated the acquisition of foundational reading skills. The study concludes that AR technology holds substantial potential as an innovative tool for early literacy instruction, although its implementation requires sufficient infrastructure and proper user training. Beyond its local implementation, this study contributes to the broader international discussion on technology-enhanced literacy instruction by demonstrating how pedagogically grounded AR design can support early reading engagement and multimodal learning in primary education.

Keywords: Augmented Reality, reading module, Fuzzy Delphi Method, early literacy

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INTRODUCTION

Contemporary education is closely aligned with the demands of the 21st century and the Fourth Industrial Revolution (IR 4.0). Despite global efforts to improve early literacy, many education systems continue to face challenges in ensuring that children achieve minimum reading proficiency during the early years of schooling. According to UNESCO reports, a considerable proportion of pupils worldwide still struggle to master foundational reading skills by the end of primary education. These challenges highlight the need for innovative instructional approaches that integrate digital technologies to support engagement, comprehension, and effective literacy instruction among early learners.

Curriculum reforms now prioritise technology integration, especially in developing Malay language reading skills (Ministry of Education Malaysia, 2018). This approach reflects the digital-native characteristics of today's learners, who prefer mobile devices such as smartphones and tablets, and respond well to play-based learning methods (Steinmaurer et al., 2020).

Game-based learning, which combines gameplay and educational goals, has proven to be an effective instructional strategy (Nadolny et al., 2020). Similarly, the use of Information and Communication Technology (ICT) supports interactive and engaging learning environments that promote digital literacy from an early age (Hendrayana & Wahyudin, 2018; Pitchford et al., 2021). ICT has long been integral to teaching and learning Malay reading skills, serving both as an instructional aid and a learning support tool. This aligns with the Primary School Standard Curriculum (KSSR), which emphasises ICT integration to strengthen language comprehension and literacy (Ministry of Education Malaysia, 2018). Teachers act as facilitators, and the success of ICT use depends on content quality and learner readiness (Abdul Rahim et al., 2021; Ahmad Jusoh et al., 2020). Emerging technologies such as Augmented Reality (AR) are especially promising for enhancing attention, engagement, and participation in reading lessons.

The Malaysia Education Blueprint 2013–2025 also promotes a shift from teacher-centred to student-centred approaches. It highlights facilitative pedagogy, classroom flexibility, and active learning to encourage higher-order thinking (Ministry of Education Malaysia, 2013). Teachers are expected to act as planners, facilitators, and assessors to ensure pupils' active participation. Effective teaching also incorporates Cross-Curricular Elements such as science, technology, and ICT. Beyond knowledge acquisition, ICT encourages scientific thinking, real-world application, and more meaningful learning experiences.

Teaching methods in Malay language education have evolved to meet modern educational needs (Ahmad et al., 2023). Various approaches, including *Bijak ABC*, *Oral-Aural*, *Phonics*, *Bisuka*, *I-Sina*, and *Borosman*, have been introduced (Ahmad et al., 2023). Since 1995, strategies such as phonics, alphabet-based learning, syllable segmentation, and word construction have supported reading instruction in primary schools (Jamian, 2021; Husin, 2013). These initiatives were strengthened through the Literacy and Numeracy Screening (LINUS) programme. However, several limitations in foundational reading approaches remain, contributing to pupils' ongoing difficulties in mastering basic reading skills (Ying & Mahamod, 2024).

Although AR has been widely explored in science and STEM education, relatively limited research has focused on the pedagogical design of AR applications specifically for early reading development. Many existing studies emphasise technological functionality or user engagement rather than examining how AR elements can be systematically designed to support literacy learning processes. Therefore, there remains a need to investigate how AR-based instructional design can support foundational reading development in early primary education.

LITERATURE REVIEW

The Evolution of Augmented Reality in Malaysia Education

The integration of Augmented Reality (AR) in Malaysian education reflects the nation's broader commitment to advancing digital learning. AR has been recognised as a transformative tool that merges physical and virtual elements to create interactive and immersive learning experiences (Azuma, 1997; Bacca-Acosta et al., 2014). Over the past decade, local institutions such as Universiti Pendidikan Sultan Idris (UPSI), Universiti Tun Hussein Onn Malaysia (UTHM), and Universiti Sains Malaysia (USM) have pioneered the exploration of AR for teaching, learning, and training across disciplines (Kouch, 2021).

Early AR initiatives in Malaysia primarily focused on Science, Technology, Engineering, and Mathematics (STEM) subjects, where interactive visualisations helped improve pupils' conceptual understanding and motivation (Surdi et al., 2025). In recent years, AR adoption has expanded into language learning and vocational training, offering new ways to enhance communication, creativity, and practical skills (Halim et al., 2020; Jalaluddin et al., 2021).

The application of AR in education supports the goals of the Malaysia Education Blueprint 2013–2025, which emphasises digital innovation, creativity, and lifelong learning. AR aligns with the nation's aspiration to integrate Industrial Revolution 4.0 technologies into education, encouraging interactive, learner-centred, and experiential learning approaches. However, its implementation still faces challenges such as limited teacher readiness, infrastructure constraints, and the need for quality AR-based educational content (Rashid et al., 2021; Tan & Lee, 2022). Therefore, collaboration among key stakeholders including policymakers, educational institutions, and content developers is vital to ensure the effective and sustainable integration of AR technology in classroom practices.

Benchmarking against global studies reveals that AR applications have demonstrated substantial pedagogical value across various contexts. For instance, Bacca-Acosta et al. (2014) reported that AR promotes active learning and enhances motivation in science education through interactive and immersive experiences. Similarly, Akçayır and Akçayır (2017) found that AR facilitates conceptual understanding, engagement, and learner satisfaction by merging digital and real-world contexts in educational settings. Similarly, Syberfeldt et al. (2016) demonstrated the use of AR to improve interactive learning in industrial training environments. Compared to these global initiatives, Didik Baca-AR uniquely addresses Malay literacy acquisition an area with limited AR-based interventions by integrating culturally relevant content and contextual visuals tailored for early primary education. This distinction underscores the application's novelty and its contribution to AR-based literacy instruction in Malaysia.

Augmented Reality in Malay Language Education: Emerging Developments

The application of AR in Malay language education is a relatively recent yet growing field in Malaysia. AR enables the combination of real-world environments with virtual objects, providing learners with an immersive experience that enhances motivation and conceptual understanding (Akçayır & Akçayır, 2017; Azuma, 1997). Unlike traditional learning methods, AR transforms abstract linguistic concepts into tangible, interactive representations, thereby fostering meaningful engagement among pupils (Bacca-Acosta et al., 2014).

In the context of Malay language learning, AR has been used to support reading, vocabulary acquisition, and pronunciation practice. Early studies demonstrated that AR can help pupils visualise letter forms, syllables, and phonetic sounds more effectively through interactive 3D models and animations (Ahmad Jusoh et al., 2020; Kouch, 2021). These features encourage active participation, strengthen cognitive associations, and promote multisensory learning experiences.

Recent developments highlight the potential of AR in addressing challenges in early literacy instruction, particularly for struggling readers. By integrating auditory and visual stimuli, AR assists learners in connecting phonemes with graphemes, which is essential in the mastery of reading skills (Bacca-Acosta et al., 2014). Furthermore, AR supports self-paced and learner-centred environments, allowing pupils to explore learning materials independently while maintaining engagement and motivation (Akçayır & Akçayır, 2017).

Despite these benefits, research on AR in Malay language education remains limited compared to other subject areas such as science and mathematics. Existing studies primarily focus on usability and user perception, with few addressing pedagogical design or learning outcomes. Therefore, further investigation is needed to evaluate the pedagogical effectiveness of AR applications and to explore their role in enhancing literacy, especially at the primary school level.

Addressing this gap, the present study aims to design and develop an AR-enhanced reading module—Didik Baca-AR—tailored for early primary education. Focusing on the design phase utilizing the Design, Develop, and Research (DDR) model, this study systematically structures interactive 3D visualisations, phonetic audio, and syllable configurations to support the teaching and learning of foundational Malay reading skills. The application emphasises participatory learning through play-based interactivity, aligning with the goals of the Malaysia Education Blueprint 2013–2025 to enhance literacy through digital innovation. By explicitly grounding the design in cognitive and constructivist theories, this research not only responds to localised curricular needs but also contributes to the broader international discourse on how AR can be pedagogically engineered to support early literacy acquisition.

METHOD

This study employs the DDR approach proposed by Richey and Klein (2007). DDR is a systematic research process comprising four phases: needs analysis, design, development, and evaluation. Its primary aim is to generate empirical evidence for the creation of a new product, model, or an evolved version of an existing model (Osman, 2017; Richey & Klein, 2007), thereby enhancing its validity and robustness (Muhammad Sabri et al., 2012).

DDR consists of two main types. Type 1 focuses on designing and developing new models while generating new theories, methodologies, and testing approaches within novel contexts (Richey & Klein, 2007; Saedah et al., 2020). Type 2, on the other hand, emphasises research involving specific models through programme design, development, or project evaluation, with conclusions drawn from particular aspects (Tracey, 2009). Several studies have adopted this approach; for instance, Tracey (2009) utilised DDR Type 2 as a framework for a design and development model, while Lee (2014) and Lee and Jang (2017) developed and validated new instructional frameworks within educational contexts. In the present study, DDR Type 2 was adopted, focusing specifically on the design and development phases. These two phases, originally distinct, were combined to streamline the research process and ensure a more cohesive workflow.

According to Seels and Richey (1994), the design phase refers to the planning process for constructing detailed specifications. This phase is considered the most critical as it involves strategic actions that enhance the credibility of the research through the application of multiple research methods (Richey & Klein, 2007). In this study, the scope is limited to designing elements and developing the content of the Didik Baca-AR application for Year One primary school pupils. A quantitative checklist method was employed to collect data through questionnaires administered to 10 experts. For the construction of the questionnaire protocol, two experts served as content evaluation panellists (Lawshe, 1975). The sampling technique used was purposive sampling, specifically judgement sampling, whereby participants were selected based on their expertise in the subject area. This method allows for the collection of relevant and precise information from knowledgeable individuals (Sekaran & Bougie, 2011). The data obtained from the checklist were used to guide the design of the Didik Baca-AR application's elements and content, which subsequently served as the foundation for the development phase.

The development phase, described by Seels and Richey (1994) as the production stage, involves the implementation of design specifications. In this phase, the focus was on developing the Didik Baca-AR prototype, which was validated by 10 experts. The primary objective of this phase was to produce a high-quality prototype suitable for classroom application. The Fuzzy Delphi Method (FDM) was employed an advanced version of the classical Delphi technique introduced by Dalkey and Helmer (1963) as it offers several advantages in obtaining expert consensus. A homogeneous sample of 10 experts participated in this phase, comprising two language experts, two pedagogy experts, two reading skills specialists, three AR specialists, and two technology experts. This number was deemed appropriate for the context of the study, as a sample that is too large may hinder the process of reaching expert consensus (Mohd Ridhuan & Nurulrabihah, 2020). For questionnaire validation, six experts were appointed to review the linguistic and content accuracy. The feedback gathered from these experts was used to refine the pedagogical, technical, and content aspects of the module before progressing to the evaluation and usability testing phase. Table 1 illustrates the research flow based on the DDR approach.

Table 1. Design and Development Research (DDR) approach

Phase (2)	Respondent	Instrument	Analysis
Design and Development	• Two language experts • Two Malay pedagogy experts • Two experts in reading skills • Three expert AR • One technology expert	Checklist	(%)
	• Two language experts • Two Malay pedagogy experts • Two eperts in reading skills • Three experts AR • Two technology experts	Expert validity form	Fuzzy Delphi Method Technique • Triangular fuzzy number • Threshold values

Design and Development Research

The development of this application was implemented in two key phases. The first phase focused on the design process, followed by the second phase, which centred on the development of the application. Activities undertaken during the design phase included the selection of relevant content, the compilation of supporting materials, and the creation of a storyboard to outline the structure and content delivery of the application.

The content design of this application module focuses on the development of reading instructional materials based on AR technology, guided by the Year One Malay Language Standard Curriculum and Assessment Document (DSKP). The content was developed using a tutorial-based learning strategy, integrated into the Buildbox Classic and Makar platforms, resulting in a user-friendly application that is easily accessible via the Google Play Store and Apple App Store.

Three main sources were utilised in the development of the content: learning materials (texts, videos, illustrations), instructional resources, and reference materials for dissemination systems. The content was designed based on the national textbook, relevant modules, and supplementary resources to ensure the appropriateness and alignment of concepts with the teaching and learning processes of the Malay language. The storyboard was developed as a visual planning tool to represent the structure, navigation, text elements, and interactive features of the application. It plays a crucial role in organising the content flow and guiding system developers in designing the instructional components.

A questionnaire using a Yes/No scale was also distributed for the purpose of triangulating the findings, involving ten experts in the design phase. Meanwhile, content validation was conducted with the participation of eleven experts using the FDM. This method enabled the researcher to obtain expert consensus on the suitability of the learning objectives, content, strategies, and media used (Abdul Rahim et al., 2018; Mohamad et al., 2015). The evaluation was based on three main criteria: threshold value (d), percentage of agreement, and fuzzy score (A). This approach facilitated systematic refinement of the content based on expert input.

The Development Process of the Didik Baca-AR Application

The development of the Didik Baca-AR application involved a structured process including content selection, storyboard development, interface design, and AR integration. Detailed technical descriptions are summarised to emphasise the pedagogical design of the learning application.

Principles of the Didik Baca-AR Application Development

The development principles of the Didik Baca-AR application are grounded in the eight elements of an Augmented Reality (AR) system as proposed by Novak (2012), which served as a framework to guide the researcher in designing the application content. These elements include: (1) user, (2) interaction, (3) device, (4) server, (5) virtual content, (6) real content, (7) physical world, and (8) transmission. Table 2 outlines each of these AR system elements as applied in the development of the Didik Baca-AR application content.

Table 2. AR system elements in the development of Didik Baca-AR application content

No.	AR system elements	Description	Study context
1	User	The individual who manipulates, controls, and receives the AR system.	Year one pupils are the users of the Didik Baca-AR application developed for this study.
2	Interaction	The system's response through interactions between the user and the AR device, virtual content, and the physical world.	The Didik Baca-AR application responds to interactions between year one pupils and the AR device (smartphone), the virtual content (letters, sounds), and the physical world (real-time generated visuals and audio via AR).
3	Device	Hardware components including sensors, processors, and display units that align the physical world, real content, and the user's location.	Smartphones used by pupils run the Didik Baca-AR application and are equipped with sensors, processors, and displays capable of generating and displaying letters and sounds. Devices used in this study are Android smartphones version 10 and above.
4	Server	The data source and processing functions that are not embedded within the device.	Didik Baca-AR utilises Buildbox Classic and the Makar web platform as external servers to detect and track image targets and objects. These platforms do not require installation on the user's device.
5	Virtual Content	Additional information generated by the smartphone and delivered to the user through the AR device.	Virtual content in this application includes animated letters and phonemes accompanied by synchronised audio output.
6	Real Content	Data presented directly from the real-world physical context.	AR marker cards representing letters, syllables, and reinforcement activities serve as real objects to trigger virtual teaching content.
7	Physical World	Refers to the actual environment and tangible objects experienced by the user.	The Didik Baca-AR application considers this element to ensure that digital content interacts seamlessly and meaningfully with the real-world environment.
8	Transmission	The process of generating virtual content in alignment with the physical world.	The smartphone camera detects the image on the AR marker card or barcode, based on distance and angle, to generate and project the moving letters and corresponding audio.

(Source: Novak, 2012)

Augmented Reality Reading Application Flow Chart

The researcher designed a flowchart as a framework to guide the instructional delivery process within the learning application. According to Rozinah (2005), a flowchart is a logical diagram that illustrates the steps involved in a development process (Rozinah, 2005). Similarly, Mohamad Ali (2019) emphasises that a flowchart represents the navigation or sequence of activities aimed at facilitating effective and positive learning experiences. Figure 1 presents the content structure flowchart outlining the sequence of processes embedded in the developed Augmented Reality (AR) learning application.

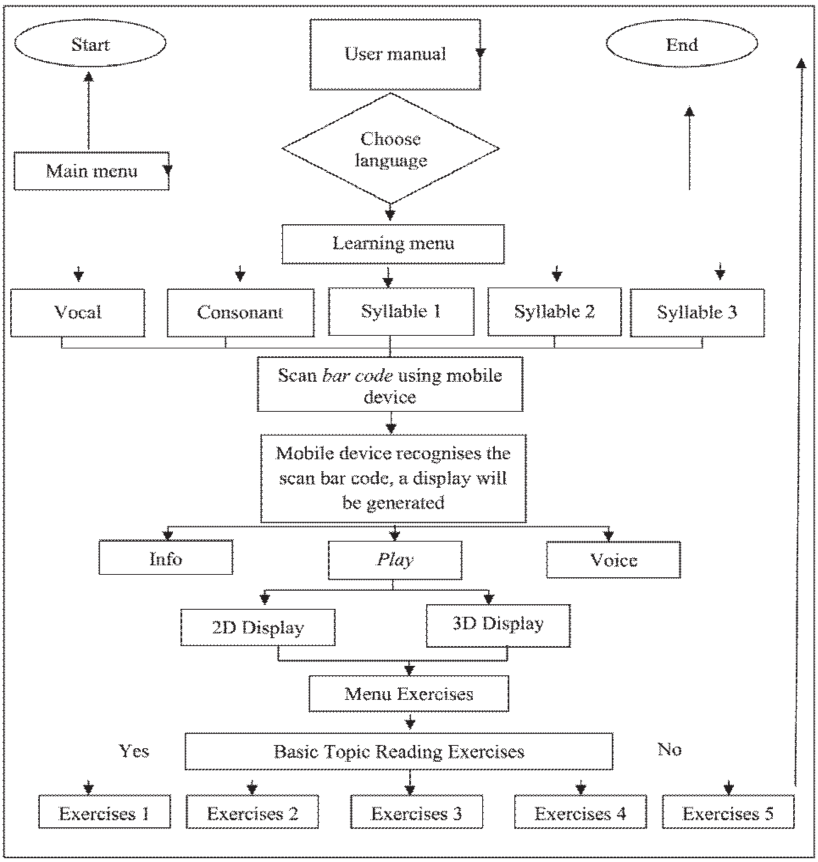

Figure 1. Flowchart illustrating the content structure of the Didik Baca-AR Application

Storyboard Representation of the Didik Baca-AR Learning Application

The storyboard played a crucial role in documenting the technical and visual design of the Didik Baca-AR application. It served as a visual framework integrating multimedia elements such as text, graphics, animations, and videos to ensure coherent instructional flow and effective user experience. According to Yuliarni et al. (2019), a storyboard provides conceptual insights into instructional materials and functions as a detailed guide that supports the systematic development of multimedia resources.

The storyboard for Didik Baca-AR was developed to illustrate the overall structure and navigation of the learning application (Mohamad Ali, 2019). Elements including text, audio, animation, and graphics were arranged sequentially and systematically to align with the application's learning objectives. This design framework served as the primary reference throughout the development process, ensuring consistency between pedagogical intent and multimedia execution.

The Main Menu Interface of the Developed Didik Baca-AR Application

The main menu interface of the application displays the home page, topics, language selection menu, exit button, and user manual button. Figure 2 illustrates the complete user interface of the application, developed based on the storyboard. Each function within the interface is labelled with an indicator code corresponding to specific menu features in the application.

Figure 2. The Complete user interface of the main menu in the Didik Baca-AR Application

Table 3 provides a brief description of the functions associated with each indicator code in the main menu interface of the Didik Baca-AR application.

Table 3. Description of functions for each indicator code in the main menu interface of the Didik Baca-AR application

Indicator	Item	Description
A1	Share Button	Allows users to share the applications with others.
A2	Main Menu	Button to access the learning materials.
A3	Navigation Menu	Allows users to return to the previous screen, select a different activity or repeat a learning session.

Learning Menu Interface of the Didik Baca-AR Application

The learning menu interface of the Didik Baca-AR application was designed to support structured literacy learning by organising content into vowel recognition, consonant recognition, and practice activities. This hierarchical structure enables pupils to progress gradually from basic letter identification to syllable construction, which aligns with early reading development principles. The interface layout also facilitates intuitive navigation, allowing pupils to access learning activities independently and reinforcing self-directed learning within a digital environment.

Interface Display of the Syllable Menu Storyboard in the Developed Didik Baca-AR Application

The interface of the Didik Baca-AR application was intentionally designed with a simplified and visually structured layout to support young learners' cognitive processing. By minimising interface complexity and highlighting key navigation buttons, the design reduces cognitive load and enables pupils to focus on phonological and visual learning tasks. This approach aligns with principles of multimedia learning and supports early readers who require clear visual cues and guided interaction when engaging with digital learning environments.

Interface Display of the Reinforcement Activity Report in the Didik Baca-AR Application

The reinforcement activity interface was designed to strengthen pupils' understanding of syllable recognition through interactive practice tasks. The use of multiple-choice questions allows pupils to test their comprehension while receiving immediate feedback, which is essential for reinforcing phonological awareness in early reading development. This interactive reinforcement approach supports active learning and enables pupils to consolidate newly acquired reading skills through repeated practice. Overall, the interface design of the Didik Baca-AR application emphasises simplicity, guided interaction, and multimodal engagement to support early literacy development. By integrating visual cues, phonetic audio, and interactive navigation, the application provides a learning environment that facilitates pupils' understanding of letter-sound relationships and syllable formation.

Content Structure of the Didik Baca-AR Application

The design of the Didik Baca-AR application incorporates several key components that ensure effective instructional delivery. Instructional materials were developed according to learners' visual perception standards and the fundamental principles of multimedia design (Wan Ahmad et al., 2021). These components are essential in fostering interactive communication and engagement within an AR-based learning environment.

The integration of multimedia elements text, graphics, video, animation, audio, and interactivity form the foundation of the AR system displayed on mobile devices (Harun & Tasir, 2003). Each element was designed to complement one another, creating an immersive and cohesive learning experience. A detailed breakdown of the application's content structure is presented in Table 4.

Table 4. Structure of content design in the Didik Baca-AR application

Structure	Multimedia elements				Description (info)
	Text	Graphics	Audio	Animation	
Main Menu Page	✓	✓	×	×	Displays main navigation with text labels and basic visual icons.
3D Objects	✓	✓	✓	✓	Interactive three-dimensional representations with narration and motion.
2D Objects	✓	✓	✓	✓	Two-dimensional visuals with supporting narration and movement.
Exercise	✓	✓	×	×	Practice activities with visual cues and simple animations.
AR Camera Functionality	×	×	×	✓	Camera-based AR interface displaying animated digital overlays.
Marker Cards	✓	✓	×	×	Physical cards with printed triggers for AR content, used in reading activities.

Source: The AR application content is based on the multimedia design principles proposed by Harun and Tasir (2003).

Software Used in the Development of the Didik Baca-AR Application

The development of the Didik Baca-AR application employed four main software tools: BuildBox Classic, Makar, Audacity, and Autodesk 3ds Max. The careful selection of these platforms ensured smooth functionality, user-friendliness, and the integration of multimedia and AR elements into the application.

BuildBox Classic served as the primary platform for developing the application's interface and functionality. It supports 3D environments suitable for mobile, desktop, and web-based AR learning applications (Shamsudin & Abd Majid, 2018). Makar was used as the Augmented Reality Software Development Kit (AR SDK), enabling the synchronisation of digital content with real-world environments. This software incorporates ARToolKit functions for marker-based object recognition and real-time interaction (Kato et al., 2000). Vuforia was also integrated to enhance tracking accuracy through computer vision technology, enabling real-time detection of 3D models and image targets (Reilly et al., 2017).

Audacity was used to produce and edit audio narration within the application. Its open-source flexibility and user-friendly interface allowed the creation of clear phonetic sounds and descriptive voiceovers that support learners' auditory engagement (Thompson, 2014).

Finally, Autodesk 3ds Max was utilised to design and animate 3D objects, including geometric shapes and their unfolded (net) representations. These models were imported into BuildBox Classic and Makar to enhance interactivity and visual realism.

Expert Checklist Findings

An expert checklist evaluation was conducted to validate the Didik Baca-AR prototype. The assessment involved ten experts comprising lecturers and teachers specialising in language education, educational technology, and Malay language instruction. Their professional input ensured that the application met the intended learning objectives and adhered to sound pedagogical design principles.

Expert validation was crucial to confirm the alignment of AR content with the instructional goals prior to implementation, consistent with Peterson's (2000) emphasis on the role of subject-matter experts in verifying pedagogical accuracy and design fidelity. The experts reviewed the application's objectives, content relevance, interface design, and multimedia integration. Revisions were subsequently made based on their feedback to enhance overall quality and usability. Table 5 presents the demographic information and areas of expertise of the participating experts.

Table 5. Expert demographics and areas of expertise

Expert	Expert title	Institution	Area of expertise	Years of experience
1	Associate Professor Dr.	Public university	Language and Linguistics	15 years
2	Head of School, Dr.	Public university	Malay Language Education, Pragmatics and Sociolinguistics	18 years
3	Senior Lecturer, Prof. Dr.	Public university	Malay Language Education	25 years
4	Teacher, Dr.	Primary school	Malay Language Education	10 years
5	Senior Lecturer, Dr.	Teacher Education Institute	Malay Language Education	8 years
6	Senior Lecturer, Dr	Teacher Education Institute	Malay Language Education	9 years
7	Associate Professor Dr.	Public university	Technical and Vocational Education and Training, Augmented Reality	13 years
8	Senior Lecturer, Ts. Dr.	Private university	Animation Design and Application Development	12 years
9	Assistant Director, Ts. Dr.	State Education Department	Educational Technology and Augemented Reality	10 years
10	Head of Innovation Centre, Prof. Ts. Dr.	Public university	Malay Language Education and Mobile Applications	8 years

The checklist instrument comprised 46 items categorised under seven constructs evaluated by experts: (i) hardware selection, (ii) learner needs, (iii) teaching and learning objectives, (iv) application content, (v) user interface layout, (vi) activity integration, and (vii) learning outcome assessment. Content validity for the Didik Baca-AR application was determined based on the guidelines by Tuckman and Waheed (1981). The scoring method involved dividing the total score assigned by the experts by the maximum possible score and multiplying by 100. A mastery or achievement level exceeding 70% (> .70) was considered acceptable or indicative of a high level of attainment. Table 6 presents the evaluation results of the Didik Baca-AR application, based on expert feedback from ten participants, across the seven evaluation domains: hardware selection, learner needs, teaching and learning objectives, application content, user interface layout, activity integration, and learning outcome assessment.

Table 6. Presents the results of the evaluation of the Didik Baca-AR application based on expert checklist feedback

No.	Construct	N	Validity achievement (%)	Validity coefficient (1.00)
1.	Hardware	10	50.00	.50
2.	Learner requirements	10	96.00	.96
3.	Teaching and learning objectives	10	100.00	.100
4	Application content	10	92.86	.93
5.	Interface layout	10	100.00	.100
6.	Activity structure	10	99.00	.99
7.	Learning assessment	10	100.00	.100
	Overall average		91.12	.91

Based on Table 6, the overall average content validity achievement from the checklist evaluation by 10 experts was 91.12%, with a content validity coefficient of .91. Therefore, the overall expert validation score for the Didik Baca-AR application indicates a high level of validity (> .70), suggesting that the application is well-suited for implementation among year one pupils.

FINDINGS

Design and Development Phase

The FDM findings indicate that consensus was achieved among the 10 experts, accompanied by revisions and suggestions for improving specific items in the instrument. The reviewed items demonstrated good content validity. Overall, all constructs were accepted based on expert consensus, with agreement values meeting the required thresholds. Consequently, all seven constructs comprising 37 items were retained for the development of the Didik Baca-AR application prototype. Table 7 presents the research findings based on the consensus of 10 experts.

The FDM results, derived from a panel of 11 experts, yielded a strong consensus on all seven constructs. Ultimately, 37 of the original 46 proposed items met the strict acceptance criteria (threshold ≤ 0.2 and expert consensus ≥ 75%). This finding suggests that interactive visualisation, phonetic audio, and multimedia integration are considered essential components in supporting early literacy development. These elements facilitate multisensory learning experiences that strengthen the connection between phonemes and graphemes, which is a critical process in early reading acquisition.

Table 7. Presents the research findings based on the Fuzzy Delphi Method

No of item	Triangular fuzzy numbers (value)		Defuzzification process				Expert consessus
	Value threshold, *d*	Expert agreement percentage	m1	m2	m3	Score fuzzy A	
Construct 1: Equipment							
1. Internet facilities	0.124	82%	0.809	0.936	0.982	0.909	ACCEPTED
2. Laptop	0.163	82%	0.791	0.918	0.964	0.891	ACCEPTED
3. Smart phone	0.065	91%	0.864	0.973	0.991	0.942	ACCEPTED
4. Tablet/iPad	0.081	91%	0.845	0.964	0.991	0.933	ACCEPTED
Construct 2: Student Need							
1. Internet facilities	0.124	82%	0.809	0.936	0.982	0.909	ACCEPTED
2. Usage guide	0.092	1%	0.827	0.955	0.991	0.924	ACCEPTED
3. Room for interaction between students and students	0.203	82%	0.791	0.909	0.945	0.882	**REJECTED**
4. Easy icon	0.174	91%	0.791	0.918	0.955	0.888	ACCEPTED
5. Clear interface display	0.161	91%	0.827	0.936	0.955	0.906	ACCEPTED
6. Appropriate use of time	0.131	91%	0.809	0.936	0.973	0.906	ACCEPTED
7. Directed learning instructions	0.025	100%	0.882	0.991	1.000	0.958	ACCEPTED
8. Room for interaction between teacher and students	0.233	73%	0.755	0.882	0.936	0.858	**REJECTED**
9. Teacher supports the implementation of applications	0.127	82%	0.791	0.927	0.982	0.900	ACCEPTED
10. Easy navigation	0.127	82%	0.791	0.927	0.982	0.900	ACCEPTED

(Continued on next page)

Table 7. *(Continued)*

No of item	Triangular fuzzy numbers (value)		Defuzzification process				Expert consessus
	Value threshold, *d*	Expert agreement percentage	m1	m2	m3	Score fuzzy A	
Construct 3: Teaching and Learning Objectives							
1. Clear teaching objectives	0.025	100%	0.882	0.991	1.000	0.958	ACCEPTED
2. Objectives focus on the Curriculum and Assessment Standard Document (DSKP)	0.025	100%	0.882	0.991	1.000	0.958	ACCEPTED
3. Objectives focus on assessment elements	0.092	91%	0.827	0.955	0.991	0.924	ACCEPTED
Construct 4: Application Content							
1. The content is appropriate according to the student's level	0.025	100%	0.882	0.991	1.000	0.958	ACCEPTED
2. The content is relevant to the latest developments	0.045	100%	0.864	0.982	1.000	0.948	ACCEPTED
3. The applications content is divided according to the topic	0.045	100%	0.864	0.982	1.000	0.948	ACCEPTED
4. 'Chat Box' is provided for interaction	0.076	100%	0.809	0.955	1.000	0.921	ACCEPTED
5. Problem solving to assist teaching and learning	0.099	91%	0.809	0.945	0.991	0.915	ACCEPTED
6. Use appropriate language	0.025	100%	0.882	0.991	1.000	0.958	ACCEPTED
7. Appropriate audio	0.169	91%	0.809	0.927	0.955	0.897	ACCEPTED

(Continued on next page)

Table 7. *(Continued)*

No of item	Triangular fuzzy numbers (value)		Defuzzification process				Expert consessus
	Value threshold, *d*	Expert agreement percentage	m1	m2	m3	Score fuzzy A	
Construct 5: Application Interface Display Layout							
1. Standard presentation of engaging content	0.161	91%	0.827	0.936	0.955	0.906	ACCEPTED
2. Arrange the appropriate display layout	0.025	100%	0.882	0.991	1.000	0.958	ACCEPTED
3. The use of icons in the application is interesting	0.045	100%	0.864	0.982	1.000	0.948	ACCEPTED
Construct 6: Activity Completion Arrangement							
1. Selection of appropriate activities	0.025	100%	0.882	0.991	1.000	0.958	ACCEPTED
2. Teaching activities comply with DSKP	0.100	91%	0.791	0.936	0.991	0.906	ACCEPTED
3. Learning support activities	0.205	82%	0.773	0.900	0.945	0.873	**REJECTED**
4. Activities that motivate students	0.203	82%	0.791	0.909	0.945	0.882	**REJECTED**
5. Interaction activities help students communicate with each other	0.205	82%	0.773	0.900	0.945	0.873	**REJECTED**
6. Activities can help solve problem individually	0.092	91%	0.827	0.955	0.991	0.924	ACCEPTED
7. Activities content that attracts students' attention	0.124	82%	0.809	0.936	0.982	0.909	ACCEPTED

(Continued on next page)

Table 7. *(Continued)*

No of item	Triangular fuzzy numbers (value)		Defuzzification process				Expert consessus
	Value threshold, *d*	Expert agreement percentage	m1	m2	m3	Score fuzzy A	
8. Training activities can be carried out through self-learning	0.205	82%	0.773	0.900	0.945	0.873	**REJECTED**
9. Activities can help with group problem solving	0.203	82%	0.791	0.909	0.945	0.882	**REJECTED**
10. Implementation of teaching activities in line with learning outcome	0.025	82%	0.882	0.991	1.000	0.958	ACCEPTED
Construct 7: Learning Assessment							
1. Time allocated is appropriate	0.025	100%	0.882	0.991	1.000	0.958	ACCEPTED
2. Assess knowledge based on student development	0.092	91%	0.827	0.955	0.991	0.924	ACCEPTED
3. Motivation at every level of the game in the application	0.204	82%	0.755	0.891	0.945	0.864	**REJECTED**
4. Have a score for each student's achievement	0.081	91%	0.845	0.964	0.991	0.933	ACCEPTED
5. Provide direct feedback	0.081	91%	0.845	0.964	0.991	0.933	ACCEPTED
6. Monitoring progress students implementing learning activities	0.092	91%	0.827	0.955	0.991	0.924	ACCEPTED
7. The content has continuity with the final assessment of the application	0.092	91%	0.827	0.955	0.991	0.924	ACCEPTED

For Construct 1 (Hardware), experts decisively rejected the use of desktop computers in favour of mobile and tablet devices. Analytically, this aligns with the tactile, active learning principles of Constructivist Theory; young learners require the spatial freedom to manipulate physical marker cards and scan them with a mobile lens to merge physical and digital realities effectively. The item related to desktop computer usage was rejected due to its incompatibility with mobile learning platforms, consistent with Razali and Khalid (2021), who found that mobile applications are optimised for smaller computing devices.

For Construct 2 (Pupils Needs), items concerning pupil-to-pupil and teacher-to-pupil interaction spaces were excluded, as these exceeded the threshold value and received low consensus. Experts noted that teacher-to-pupil interaction is facilitated externally through teacher guidelines rather than embedded within the app. This supports Mohamad Ali (2019) view that self-directed, technology-assisted tools can promote independent learning without constant teacher facilitation.

All items under Constructs 3 (Teaching and Learning Objectives), 4 (Application Content), and 5 (User Interface Layout) were accepted, demonstrating expert agreement on the pedagogical relevance and usability of these components. These findings align with Yaakob (2017), who similarly validated constructs in mobile learning design.

For Construct 6 (Activity Content Structure), several items were excluded due to misalignment with the application's focus on foundational reading. Items related to "supportive learning activities," "motivation," and "strict adherence to DSKP" were removed, as experts emphasised that meaningful learning requires balanced, engaging, and flexible activities rather than rigid curriculum replication Razali and Khalid (2021). Similarly, items promoting excessive self-directed learning or entertainment-focused content were rejected, as they may reduce instructional focus (Tangkui, 2021) and pose monitoring challenges (Houle, 1961). These results affirm that expert consensus (threshold ≤ 0.2) is essential in refining content relevance (Cheng & Lin, 2002; Chen et al., 2016).

Under Construct 7 (Learning Assessment), the item "motivation at each level of gameplay" was excluded as it did not align with the intended assessment objectives. Experts emphasised that motivational features alone do not directly evaluate learning effectiveness, a finding consistent with Mohd Fikruddin et al. (2021), who highlighted that motivation-based indicators often measure engagement rather than actual learning outcomes.

Overall, the validation process confirmed that the Didik Baca-AR application was developed based on the needs of Malay language teachers and adheres to the DDR model (Richey & Klein, 2007). It integrates the Cognitive Development Theory, Multiple Intelligences Theory, and the Interactive Reading Model as its pedagogical foundation. The application aligns with the Malay Language Curriculum Standards and was refined through expert consensus to ensure pedagogical coherence and technical usability.

Usability testing conducted with Year One Malay language teachers further confirmed that the Didik Baca-AR application met expectations for classroom implementation. Teachers found it effective, appropriate, and reliable for improving pupils' phonemic awareness, syllable reading, and overall literacy performance.

DISCUSSION AND CONCLUSION

This study presents phase 2 of the Didik Baca-AR project, focusing on the design and development of an AR application for foundational Malay reading skills. The content and interface design were developed in accordance with the DSKP for Year One. The design and validation of the Didik Baca-AR application offer critical insights into the intersection of Augmented Reality, early literacy, and cognitive processing. A central tension in educational technology design is balancing the immersive, highly stimulating nature of AR with the limited working memory capacity of early learners. By rigorously applying the FDM this study reveals that experts strongly favour stripping away extraneous digital features such as embedded pupil-to-pupil chat functions and superficial gamified rewards in favour of targeted, multisensory phonetic scaffolding.

This consensus provides a vital practical extension of Sweller's (1988) Cognitive Load Theory within AR environments. While AR inherently increases intrinsic cognitive load due to its dual-processing demands (navigating physical marker cards while processing digital overlays), the validated design of Didik Baca-AR demonstrates that extraneous load can be mitigated by maintaining a strict pedagogical focus on grapheme-phoneme mapping. The application's reliance on 3D visualisations and synchronised phonetic audio serves specifically to anchor abstract linguistic concepts, ensuring that the technology acts as a cognitive bridge rather than a digital distraction.

Furthermore, the validated module operationalises Constructivist Theory (Piaget, 1952) by transforming the traditionally passive experience of rote phonetic memorisation into an active, tactile learning process. Pupils are required to physically manipulate marker cards to trigger syllables, engaging their spatial and kinaesthetic intelligences alongside auditory and visual modalities (Gardner, 1983). Rather than passively consuming digital content, learners construct meaningful linguistic associations through direct physical-digital interaction. The high expert validity achieved in this phase underscores that AR is most pedagogically effective when it facilitates active learner agency rather than mere content consumption.

This study establishes a validated, theory-driven framework for the design of AR elements in early reading modules. By prioritising pedagogical coherence over technological excess, the Didik Baca-AR application offers a scalable model for addressing foundational literacy challenges. However, as this research is bounded by the design and development phases of the DDR model, its findings are inherently limited to expert pedagogical consensus. The true efficacy of AR in mitigating literacy deficits cannot be fully realised through design validation alone. Therefore, the next crucial phase of this research, Phase 3: Usability Evaluation, will involve empirical, longitudinal usability evaluations within authentic classroom settings. The design principles identified in this research demonstrate how

Augmented Reality can support multimodal learning engagement and interactive reading experiences among early learners. These findings provide transferable insights for educators and researchers seeking to design AR-supported literacy tools in diverse linguistic and cultural contexts.

Future studies must investigate not only the technological usability of the module but its measurable impact on pupils' phonemic awareness, reading fluency, and cognitive retention, of the application through classroom implementation and experimental studies thereby closing the loop between instructional design and empirical learning outcomes.

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