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Enhancing Primary School Students' Learning Experiences and Emotions with Interactive AR Textbooks: A design-based research approach

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Abstract
This study explores augmented reality (AR) to enhance primary school students' learning experiences and emotions using interactive textbooks. Employing a design-based research (DBR) methodology, it examines AR-assisted learning materials and their impact. The study addresses three objectives: reviewing the literature on AR learning, developing AR textbooks to enhance engagement and emotions, and providing insights for future education research. Conducted with 304 students in six Perak schools, the study demonstrates AR's potential to boost engagement, academic performance, and emotional responses. The findings highlight AR's transformative role in primary education, contributing to the development of effective and engaging learning systems.

Keywords: Augmented Reality, Interactive AR Textbooks, Design-based research (DBR), Learning experiences and emotions

1.0 Introduction
The rapid growth of technology has significantly altered the landscape of education, notably with the introduction of digital learning technologies (Almerich et al., 2024). Augmented Reality (AR) is an emerging technology that has the potential to make learning environments more interactive and engaging (AlGerafi et al., 2023). AR allows students to interact with curriculum in novel and immersive ways by superimposing digital information on the physical world. AR can enhance elementary education by boosting children' learning experiences and emotions, leading to more engaging, dynamic, and effective learning (Özeren & Top, 2023). Although the incorporation of AR into education is still in its early stages, past research indicates that AR has the potential to increase student engagement and improve learning outcomes (Kamaruzaman et al., 2022). This project investigates the potential of augmented reality (AR) to alter how primary school children interact with educational content, specifically using AR-assisted interactive textbooks. This study uses augmented reality technology to solve the challenges of traditional teaching methods and provide a solution that improves both cognitive and affective elements of learning.

2.0 Literature Review
Exploration of words, expansion of vocabulary, and enhancement of reading comprehension are essential components for the

advancement of Bahasa Melayu language and literacy (Mazlan et al., 2020). Elementary instruction in Bahasa Melayu emphasizes three key aspects of the language. Conversely, Casteleiro-Pitrez (2021) asserts that standard textbooks fail to provide active engagement, self-directed practice, or visual assistance in the specified language acquisition method. We provide interactive animated learning experiences for primary students learning Bahasa Melayu (Respati et al., 2024). The development of dynamic multimedia content, visualization techniques, and real-world connections that respond to learners' gestures and actions is essential for achieving this possibility. This will allow primary students to enhance their learning within the printed context of textbooks. They will experience substantial enhancements in language learning.

Recent years have seen an increasing interest in the application of augmented reality (AR) within educational settings (Gu et al., 2022). Research, including that by Nijhawan et al. (2023), indicates that augmented reality (AR) can provide significant educational advantages, including enhanced engagement, motivation, and improved learning outcomes. Chulpongsator et al. (2023) assert that augmented reality (AR) provides interactive visualizations, rendering it especially effective in disciplines requiring abstract thinking, including science and mathematics. Augmented reality (AR) promotes active engagement by enabling students to interact directly with learning materials, thereby enhancing their understanding and retention (Qu et al., 2022).

Design-Based Research (DBR) is a systematic approach employed in the planning and evaluation of educational interventions within real-world settings. Abdusselam and Kilis (2021) assert that Design-Based Research (DBR) is highly iterative, focusing primarily on the continuous testing, refinement, and evaluation of interventions to ensure their effectiveness. This study utilizes the Design-Based Research (DBR) methodology to direct the development and assessment of augmented reality (AR)-assisted textbooks. This methodology guarantees that the materials are grounded in theoretical and practical frameworks.

Furthermore, augmented reality has been linked to emotional and affective learning. Interactive features enhance the engagement and motivation associated with experiential learning. Pekrun et al. (2005) and Shao et al. (2023) identified students' emotional engagement as a significant factor influencing their perception of lesson content and overall academic achievement. This research aims to enhance students' cognitive outcomes and positively influence their emotional responses to learning by integrating augmented reality (AR) into textbooks.

3.0 Methodology
This study employs a Design-Based Research (DBR) methodology to guide the development, implementation, and evaluation of AR-assisted learning materials. DBR is chosen because it allows for continuous refinement of the intervention based on real-world feedback, making it particularly suited for educational innovations like AR integration.
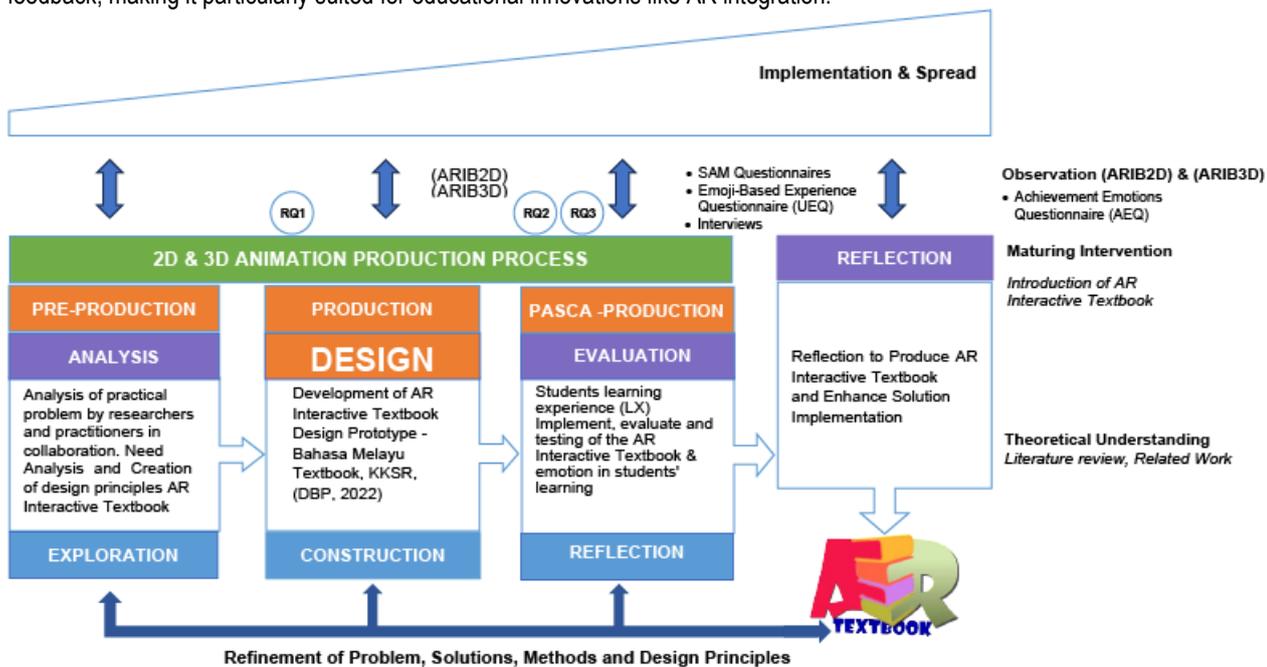

Fig. 1: Research Design using Design Based Research

The research employs a design-based research (DBR) methodology to enhance primary school students' learning experiences and emotions through the development and evaluation of interactive augmented reality (AR) textbooks. Fig. 1 show this study is segmented into two primary phases as an analysis and development, followed by evaluation and documentation. Each phase encompasses specific objectives and activities, forming a comprehensive framework aimed at creating effective AR learning materials for young students.

1.1 Phase 1: Analysis and Development

In the initial study, first-year (7-year-old) primary school students from rural and urban areas are assessed. This stage involves assessing students' initial experiences with conventional and AR-enhanced educational resources. The learning environment, preferences, and obstacles that they encounter are of interest to us. Creating Interactive AR Textbooks that are compelling necessitates this knowledge.

To enhance the learning experience, the AR interactive textbook prototype incorporates innovative features. Immersion is contributed to textbooks by AR. Physical markers function as triggers for interactive AR content, which facilitates experiential learning. Students find the learning process more engaging due to the 2D and 3D animations of the prototype. The content is tailored to the Bahasa Melayu curriculum for KSSR Year 1, ensuring that it is pertinent and appropriate for the selected educational level.

This step documents the student learning experiences (LX) with the Interactive AR Textbook. With 2D and 3D AR capabilities, the prototype provides dynamic instructional content. These elements' impact on student engagement and comprehension is quantified through systematic student feedback. These comments assist in the refinement of the prototype to ensure that it meets curricular requirements and enhances learning through interactive, innovative methods.

1.2 Phase 2: Evaluation and Documentation

In the evaluation phase, the emotional responses of students using the Interactive AR Textbooks are systematically assessed to gain insights into how this technology affects their engagement. The study is conducted in both rural and urban settings to capture a broad range of student experiences and perspectives. The primary goal is to measure emotional engagement, specifically focusing on feelings of happiness as students interact with the AR content. Two tools are used for this evaluation: Emoji-based User Experience Questions (UEQ), which provide a child-friendly way to quantify emotions, and the Self-Assessment Manikin (SAM), a non-verbal, pictorial tool that measures the intensity of emotions.

The data gathered from these tools is critical in assessing both the quality and intensity of students' emotional responses to the Interactive AR Textbook. By focusing on happiness, the evaluation helps determine whether the AR-enhanced learning environment successfully engages students and fosters a positive emotional experience. This understanding of emotional impact is crucial for improving the effectiveness of the Interactive AR Textbook and ensuring it promotes not only educational success but also enjoyable learning experiences across diverse student populations.

The final phase involves documenting the findings from the evaluation. This documentation focuses on improving the Interactive AR Textbook based on the analysed data. It also includes recommendations for further development of AR learning materials and provides insights into effective design principles. The goal is to ensure that the Interactive AR Textbooks not only enhance learning outcomes but also positively influence students' emotional engagement.

The study involved 304 students from six primary schools in Perak State, Malaysia. These schools were selected to represent a range of student demographics, ensuring that the findings could be generalized to a broader population. The students were divided into control and experimental groups, with the experimental group using AR-assisted textbooks.

The primary learning materials used in the study were AR-enhanced textbooks, developed specifically for the primary school curriculum. These textbooks included interactive elements such as 3D models, animations, and simulations that students could access using smartphones. The smartphones served as the primary digital devices for AR interaction.

Data was collected through pre- and post-tests to measure students' academic performance and engagement. Additionally, affective responses were assessed using surveys that gauged students' emotional reactions to the learning experience. Observations and interviews were conducted with teachers to gain insights into the usability and effectiveness of the AR-assisted textbooks.

The study is limited by its short intervention period, narrow content scope focused solely on Year 1 Bahasa Melayu vowels, and dependence on smartphones, which may have introduced variations in device performance and user familiarity. These constraints restrict the generalisability of the findings and limit conclusions regarding long-term learning outcomes. Future research should adopt longitudinal designs, expand AR content across subjects and grade levels, and examine broader implementation strategies to ensure effective and equitable integration of AR in primary education.

4.0 Implementation and Findings

This study employs design-based research (DBR) as its design research methodology. DBR is a four-phase process that includes Phase I (analysis), Phase II (development), Phase III (evaluation), and Phase IV (documentation). The study focusses on how interactive augmented reality (AR) textbooks can transform learning experiences and emotions among primary school students. The research examines students' emotional responses and engagement levels while using AR textbooks with different design features. The primary goal is to assess how AR design elements, particularly 2D and 3D animations, influence student enjoyment, excitement, and mastery, and how these factors collectively enhance learning outcomes.

Technology was seamlessly integrated into the subject of vocal skills learning during a 45-minute Bahasa Melayu (KSSR) Year 1 lesson by the experimental group, which utilised AR-enhanced textbooks. Throughout this period, students engage with AR content that enhances the content of traditional textbooks. Augmented reality features, such as 2D and 3D animation, interactive visuals, audio, and marker-based video, provide students with a more dynamic and engaging learning environment, thereby enhancing the teachings. By providing a multisensory learning experience that transcends text and static images, AR inputs are intended to enhance students' comprehension of the subject matter.

To ensure the successful application of AR technology, the implementation process is meticulously monitored. Teachers and

facilitators are actively engaged in the supervision of students' use of the Interactive AR Textbook, observing their level of engagement, and providing appropriate guidance. There were consistent check-ins to resolve any technical issues and guarantee the seamless integration of AR into learning activities. In addition to ensuring that students engage with content as intended and acquire mastery of the 3M (Membaca, Menulis Dan Mengira) topic vowels a, e, i, o, and u through an enhanced learning experience, the monitoring process also involves collecting feedback from students and educators to assess the efficacy of AR tools. It is possible to identify any areas for refinement and guarantee that AR-enhanced textbooks achieve their educational objectives through this comprehensive oversight.

Table 4.1 Descriptive Statistics for Emotion (Joy -D)

Items	Frequency (%), n=304								Mean	Std. deviation
	1	2	3	4	5	6	7	8		
Keseronokan	304 (100.0)	-	-	-	-	-	-	-	1.00	0.000
Rangsangan	304 (100.0)	-	-	-	-	-	-	-	1.00	0.000
Penguasaan kedudukan	222 (73.0)	82 (27.0)	-	-	-	-	-	-	1.27	0.445

Results show from Table 4.1 the students reported high levels of joy and excitement (Emotion Joy-D) when using AR textbooks, especially with 3D designs. For instance, all 304 participants consistently expressed enjoyment and enthusiasm, with a mean score of 1.00, demonstrating no variation in these emotions. The Interactive AR Textbook design effectively captured students' interest, and emotions like excitement were significantly high, showing that AR textbooks can foster a stimulating learning environment for young learners.

Table 4.2 Effect of Media Content on Learning Experience (LX)

Items	Group	Median	Mann-Whitney U	p-value
Menghalang/Menyokong	Urban	5.00	10165.000	0.129
	Rural	5.00		
Rumit/Mudah	Urban	5.00	9823.000	0.712
	Rural	5.00		
Tidak Cekap/Cekap	Urban	5.00	10041.500	0.634
	Rural	5.00		
Mengelirukan/Jelas	Urban	5.00	9930.000	0.993
	Rural	5.00		
Membosankan/Mengujakan	Urban	5.00	10092.000	0.509
	Rural	5.00		
Tidak Menarik/Menarik	Urban	5.00	9726.500	0.451
	Rural	5.00		
Konvensional/Berdaya Cipta	Urban	5.00	9984.500	0.825
	Rural	5.00		
Biasa/Canggih	Urban	5.00	9823.000	0.712
	Rural	5.00		
Overall score for *komponen afektif keseronokan pelajar*	Urban	5.00	9734.500	0.537
	Rural	5.00		

Table 4.2 shows that there is no significant difference in the effect of media content on the learning experience (LX) between Urban and Rural groups, as both groups consistently have a median score of 5.00 across all items. The Mann-Whitney U test results indicate no statistically significant differences, with all p-values exceeding 0.05. This suggests that media content, whether perceived as supportive, clear, engaging, or innovative, similarly impacts the learning experience for both Urban and Rural students.

Table 4.3 Mann-Whitney U Test for Student Emotion

Items	Group	Median	Mann-Whitney U	p-value
Saya seronok dengan cabaran mempelajari bahan pembelajaran ini.	Urban	5.00	9395.500	0.109
	Rural	5.00		

Saya seronok memperolehi ilmu baru.	Urban	5.00	9399.000	0.111
	Rural	5.00		
Saya seronok berurusan dengan bahan pembelajaran ini.	Urban	5.00	9389.000	0.105
	Rural	5.00		
Saya berasa gembira apabila membayangkan kemajuan saya dalam bahan pembelajaran.	Urban	5.00	9510.000	0.200
	Rural	5.00		
Saya belajar lebih daripada yang diperlukan sebab saya gemar belajar.	Urban	5.00	9395.500	0.109
	Rural	5.00		
Saya begitu gembira tentang kemajuan saya yang membuatkan saya bersemangat untuk terus belajar.	Urban	5.00	9448.500	0.157
	Rural	5.00		
Saya bersemangat untuk baca lebih mendalam mengenai sesetengah subjek disebabkan saya seronok dengan mata pelajaran itu.	Urban	5.00	9395.000	0.109
	Rural	5.00		
Apabila pembelajaran saya berjalan lancar, jadi saya berasa amat gembira.	Urban	5.00	9348.000	0.075
	Rural	5.00		
Saya menjadi teruja dari segi fizikal apabila pembelajaran saya berjalan lancar.	Urban	5.00	9300.500	0.049**
	Rural	5.00		
Overall score for *komponen afektif keseronokan pelajar* (Emosi Joy -E)	Urban	5.00	9464.000	0.200
	Rural	5.00		

**Significant at 5% level (p<0.05)

Table 4.3 presents the Mann-Whitney U test results for student emotion across Urban and Rural groups in terms of their enjoyment and emotional engagement with the learning materials. Both groups consistently have a median score of 5.00, showing similar positive emotional experiences. The p-values indicate no significant differences between the groups for most items, except for "Saya menjadi teruja dari segi fizikal apabila pembelajaran saya berjalan lancar," where the p-value (0.049) shows a statistically significant difference at the 5% level. This suggests that Urban and Rural students generally share similar emotional responses, except in experiencing physical excitement when learning progresses smoothly, where a slight difference exists.

Table 4.4 Effect of AR Interactive Textbook design from (ARIB2D) and (ARIB3D), on students' enjoyment component

Items	Group	Median	Mann-Whitney U	p-value
Saya seronok dengan cabaran mempelajari bahan pembelajaran ini.	ARIB2D	5.00	2318.000	0.055
	ARIB3D	5.00		
Saya seronok memperolehi ilmu baru.	ARIB2D	5.00	2322.500	0.051
	ARIB3D	5.00		
Saya seronok berurusan dengan bahan pembelajaran ini.	ARIB2D	5.00	2316.500	0.056
	ARIB3D	5.00		
Saya berasa gembira apabila membayangkan kemajuan saya dalam bahan pembelajaran.	ARIB2D	5.00	2322.000	0.047**
	ARIB3D	5.00		
Saya belajar lebih daripada yang diperlukan sebab saya gemar belajar.	ARIB2D	5.00	2318.000	0.055
	ARIB3D	5.00		
Saya begitu gembira tentang kemajuan saya yang membuatkan saya bersemangat untuk terus belajar.	ARIB2D	5.00	2309.500	0.068
	ARIB3D	5.00		
Saya bersemangat untuk baca lebih mendalam mengenai sesetengah subjek disebabkan saya seronok dengan mata pelajaran itu.	ARIB2D	5.00	2318.000	0.055
	ARIB3D	5.00		
Apabila pembelajaran saya berjalan lancar, jadi saya berasa amat gembira.	ARIB2D	5.00	2325.000	0.045**
	ARIB3D	5.00		
Saya menjadi teruja dari segi fizikal apabila pembelajaran saya berjalan lancar.	ARIB2D	5.00	2351.000	0.026**
	ARIB3D	5.00		
Overall score for komponen afektif keseronokan pelajar (Emosi Joy -E)	ARIB2D	5.00	2307.000	0.091
	ARIB3D	5.00		

**Significant at 5% level (p<0.05)

Table 4.4 presents the effect of AR Interactive Textbook design (ARIB2D and ARIB3D) on students' enjoyment component, comparing the two groups using the Mann-Whitney U test. Both ARIB2D and ARIB3D groups consistently show a median score of

5.00 across all items, indicating high enjoyment in both designs. However, significant differences between the groups are observed in three items: "Saya berasa gembira apabila membayangkan kemajuan saya dalam bahan pembelajaran" (p = 0.047), "Apabila pembelajaran saya berjalan lancar, jadi saya berasa amat gembira" (p = 0.045), and "Saya menjadi teruja dari segi fizikal apabila pembelajaran saya berjalan lancar" (p = 0.026), where ARIB3D outperforms ARIB2D. These results suggest that while both designs foster similar levels of enjoyment, the 3D version tends to enhance emotional responses more effectively, particularly in areas of physical excitement and joy related to progress in learning.

Table 4.5 ANOVA Results

Variable	Beta	t	P-value	Confidence Interval	
				Lower bound (5%)	Upper bound (95%)
Constant	4.792	34.764	0.000	4.520	5.063
ARIB (3D)	0.163	2.201	0.029**	0.017	0.309
Happy emotions	-0.027	-0.254	0.800	-0.233	0.180

**Significant at 5% level (p<0.05)   Reference category: ARIB (2D)

Table 4.5 displays the ANOVA results that examine the influence of ARIB (Augmented Reality Interactive Book) in 3D and positive emotions on the dependent variable. The constant demonstrates a highly significant value (p = 0.000) with a beta coefficient of 4.792, suggesting a robust baseline effect. ARIB (3D) demonstrates a positive and statistically significant effect (beta = 0.163, p = 0.029) at the 5% level, indicating that it has a favourable influence on the outcome when compared to the 2D reference category. Conversely, "Happy emotions" demonstrates no notable effect (beta = -0.027, p = 0.800), suggesting it does not play a significant role in the outcome. The confidence intervals provide evidence for these findings, indicating that the effect of ARIB (3D) is significant and positive.

5.0 Discussion

This study demonstrates that Interactive AR Textbooks significantly enhance both the cognitive and emotional dimensions of learning among Year 1 primary students. The high levels of enjoyment and excitement recorded align with previous findings on AR's motivational benefits (Nijhawan et al., 2023; Qu et al., 2022). Notably, the consistent responses across urban and rural schools highlight AR's potential to provide equitable learning experiences.

The stronger emotional impact of the 3D design indicates that immersive visualisation enhances affective engagement, supporting earlier research linking emotional readiness to improved learning (Pekrun et al., 2005). These outcomes reinforce the importance of carefully designed AR elements within learning materials.

The DBR approach proved effective in ensuring alignment between curriculum requirements, student needs, and technological features. The findings suggest that AR can meaningfully supplement traditional approaches in Bahasa Melayu instruction.

6.0 Conclusion & Recommendations

The findings of this study demonstrate that the Interactive AR Textbook provides substantial benefits for Year 1 students by enhancing their understanding and motivation to learn the vowels a, e, i, o, and u. The results further reveal that mobile applications integrating augmented reality serve as highly effective tools for improving students' comprehension of two-dimensional and three-dimensional design elements, thereby enriching their overall learning experience. Evidence from the study indicates that traditional teaching methods are less effective compared to blended instructional approaches that incorporate AR-based mobile applications, particularly in early literacy instruction. The implementation of the Interactive AR Textbook led to notable improvements in the academic outcomes of 314 Year 1 students in a primary school in Perak, affirming AR's potential as a complementary pedagogical tool while Bahasa Melayu textbooks continue to function as the primary instructional resource.

To enhance the effectiveness and scalability of AR-assisted learning, it is recommended that future initiatives expand AR content across multiple subjects and grade levels, provide longer-term implementation to support sustained engagement, and offer comprehensive training for teachers to facilitate seamless classroom integration. Strengthening device accessibility, improving technical reliability, and developing user-friendly AR interfaces will further optimise student engagement and learning outcomes. Collaborative efforts among educators, technologists, and curriculum designers are essential to ensure that AR innovations remain pedagogically sound, scalable, and aligned with national educational standards.

Acknowledgments

Paper Contribution to Related Field of Study

This study generates a new finding relating the issue of how interactive textbooks can improve primary education, notably in Malaysian Bahasa Melayu. Through design-based research (DBR), the research provides a framework for developing and accessing AR-assisted learning aids. With data from 304 different kids, it shows AR's dual benefits in academic performance and emotional involvement. AR content localisation emphasises the need to contextualise digital breakthroughs, enabling future research and school applications.

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