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Exploring Augmented Reality (Ar) in Malaysian Education: A Systematic Literature Review

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ABSTRACT: *This research presents a Systematic Literature Review (SLR) that explores the integration of Augmented Reality (AR) technology within the Malaysian education sector. It aims to investigate the extent of AR adoption and acceptance among both educators and learners, evaluate its effectiveness in enhancing educational outcomes, identify the factors influencing its application, and uncover the challenges and potential strategies for successful implementation. The review is guided by the five-step framework proposed by Khan et al. (2003), encompassing framing questions, identifying relevant work, assessing the qualities of the studies, summarising the evidence, and interpreting the findings. A total of 20 scholarly articles published between 2020 and 2024 were selected from Google Scholar, Web of Science, and Scopus databases and analysed using thematic analysis. The results demonstrate a growing interest in AR, particularly in early childhood and primary school contexts, with usage spanning subjects such as Science, Mathematics, Languages, and Technology. Evidence highlights AR's ability to improve student engagement, comprehension, and academic performance by offering immersive and interactive learning experiences. Nevertheless, the success of AR integration is shaped by factors including instructional design, application usability, teacher readiness, and technological infrastructure. Key obstacles identified include insufficient teacher training, lack of digital resources, and challenges in developing educational content. The findings underscore the need for strategic interventions such as tailored professional development programmes, wider access to educational technology, and comprehensive policy support for digital integration. This research offers valuable insights into the transformative potential of AR as an emerging pedagogical innovation aligned with 21st-century learning and the goals of the Industrial Revolution 4.0 in Malaysia.*

KEYWORDS*: Augmented Reality, digital education, educational technology, Industrial Revolution 4.0, systematic literature review.*

I. Introduction

The world today has undergone rapid development and human life has been significantly facilitated by advancements in technology. These include conveniences such as communication via smartphones, online financial management, and digital learning. The wave of technological innovation known as the Fourth Industrial Revolution (IR 4.0) has also brought about profound transformations in digital technology, including the education system (Rumeli, Muaza Shifa, Md Rami, & Ahmad Aizuddin, 2023). Education in the IR 4.0 era is characterised by a digitalised system that requires every element within the educational field to adapt to ongoing technological changes

(Che Sulaila Che Harun, Mashitoh Yaacob, Khairul Anwar Mastor, & Wan Zulkifli Wan Hassa, 2021). These changes encompass the use of digital learning tools and online platforms that facilitate the teaching and learning process. Teachers must equip themselves with technological competencies while students need to develop digital literacy skills to avoid being left behind in this digital age. This necessity is also emphasised in Shift 7 of the Malaysia Education Blueprint 2013–2025, which states that ICT should be leveraged to enhance the quality of learning in Malaysia (PPPM 2013–2025).

The use of ICT in the classroom combined with engaging technological elements such as audio, visuals, graphics, and animations is said to have a significant impact on enhancing the quality of teaching and learning (Ganesh Mukayah & Rosseni Din, 2021). These elements not only capture students' interest in learning but also assist them in comprehending complex concepts through the effective integration of technology in modern education. In other words, the incorporation of technological media makes the learning process more engaging and productive (Ganesh Mukayah & Rosseni Din, 2021). In line with this, the Digital Education Policy was introduced to drive the transformation of the digital education landscape, with the aim of producing a digitally fluent and competitive generation (Dasar Pendidikan Digital, 2023). Various strategies and initiatives have been developed to align with the objectives of the policy such as cultivating digitally literate students to meet the demands of the digital era and empowering educators and educational leaders to integrate digital technology into the education ecosystem. Among the technologies that can be implemented in the teaching and learning process are virtual reality (VR), artificial intelligence (AI), and augmented reality (AR).

Augmented Reality (AR) technology holds immense potential in creating more effective learning environments within Malaysia's education system, particularly in the context of an increasingly digital era. AR is a technology that integrates virtual elements with the real world, offering a more interactive and immersive learning experience. According to Nur Izza Ahmad and Syahrul Nizam Junaini (2020), augmented reality enables students to see their existing environment overlaid with digital learning content. With the aid of this technology, complex concepts can be presented in more visual and engaging ways, thereby enhancing students' understanding across various disciplines (Mohamad Hanif Jofri, Siti Nurazreen Sam, Nur Halwanie Mohd Harun, & Nurul Asyikin Jalil, 2022; Haliza Idris, Mariani Md Nor, & Mohd Nazri Abdul Rahman, 2022). Furthermore, AR is also a technology that stimulates students' thinking and boosts their motivation to learn. Singaravelu and Sivakumar (2020) assert that AR has great potential to make classrooms more engaging, informative, and easier to comprehend. AR allows students to interact with virtual objects in the real world in 3D form and this capability can significantly support students in grasping complex concepts. Despite the numerous educational benefits that AR offers, its implementation also demands appropriate infrastructure, teacher training, and equitable access to technology for all students.

In Malaysia, the integration of Augmented Reality (AR) in education remains relatively new, although it has already demonstrated significant potential in enhancing student motivation and engagement (Nurul Hafiza Mohd Pozi & Wan Shazlina Wan Ismail, 2022; Azam et al., 2024). AR technology not only provides an innovative teaching aid but also enriches the learning experience by delivering content in a more interactive and engaging manner (Ong Shu Wei & Faridah Mydin Kutty, 2022). Therefore, research on the use and effectiveness of AR in Malaysian education is highly relevant particularly in understanding user acceptance levels, its impact on learning outcomes, and the potential challenges that may arise during implementation (Fadilah Abdul Rauf & Tan Wee Hoe, 2020; Gunalan Mukatah & Rosseni Din, 2023). Although the integration of AR in education is still in its early stages, its use has the potential to introduce more dynamic and engaging learning approaches especially in subjects such as science, mathematics, language, and history. This is because complex abstract concepts can be explained more clearly, providing students with a more stimulating and meaningful learning experience.

In a research conducted by Reanuga Manikam and Siti Mistima Maat (2023), AR was found to facilitate the learning process in Mathematics. Geometry emerged as the most popular topic for AR-based teaching and learning as its abstract concepts can be represented more realistically through AR technology (Reanuga Manikam & Siti Mistima Maat, 2023). Furthermore, a research by Nur Nadia Bakim and Mohd Fadzil Abdul Hanid (2024) revealed that the

use of Augmented Reality helps improve students' visualisation skills, problem-solving abilities, and academic performance. Another research by Faizzudin Zainol Aman and Hafizhah Zulkifli (2024) demonstrated that various AR applications have been developed to support the understanding of Islamic education. Based on the available studies, it can be concluded that AR technology has become a significant tool in the teaching and learning process, as it supports the development of various student competencies and enhances their mastery of complex concepts.

Previous studies have shown that the implementation of Augmented Reality (AR) remains largely limited to individual initiatives or small-scale innovation projects and has yet to be comprehensively supported through national policies or strategic frameworks (Ong Shu Wei & Faridah Mydin Kutty, 2022). In addition, various challenges continue to hinder the effective integration of AR including infrastructural limitations, a lack of professional training for teachers, and difficulties in developing content that is both suitable and accessible (Gunalan Mukatah & Rosseni Din, 2023; Letchumanan & Karim, 2024). Furthermore, the existing body of literature on AR integration in education predominantly focuses on specific subjects or particular skills. Research examining the application of AR across multiple subjects within Malaysia's education system remains limited. There is also a notable gap in studies that explore the use of AR across various levels of education, including preschool, primary, secondary, and tertiary institutions. Additionally, previous research has paid insufficient attention to investigating the factors contributing to the effectiveness of AR as well as the challenges associated with its implementation in educational settings.

This research focuses on the implementation of Augmented Reality (AR) across various educational contexts in Malaysia, encompassing different educational levels and disciplines. The aim of this research is to analyse and examine the extent of AR usage, its acceptance, and effectiveness in enhancing learning outcomes as well as the factors influencing the integration of AR within the Malaysian education system (Letchumanan & Karim, 2024; Mohamad Roshaiqal Ameen Rosman & Mohd Norasri Ismail, 2021). Based on the primary objectives of this research, several research questions have been identified for exploration. The research questions to be addressed are as follows:

1. What is the level of usage and acceptance of Augmented Reality (AR) across various educational contexts in Malaysia?
2. To what extent is AR effective in enhancing student learning outcomes across different disciplines and educational levels?
3. What are the factors that influence the effectiveness of AR integration in education?
4. What are the challenges and potential solutions in implementing AR within the Malaysian education system?

II. Research Objectives

This research is conducted with the aim of thoroughly examining the use of Augmented Reality (AR) technology within the Malaysian education system across various levels and fields of education. The specific objectives of this research are as follows:

1. To identify the level of usage and acceptance of Augmented Reality (AR) technology in various educational contexts in Malaysia, including preschool, primary school, secondary school, and institutions of higher learning.
2. To evaluate the effectiveness of AR in enhancing student learning outcomes across various disciplines such as science, mathematics, language, history, and Islamic education.
3. To identify the factors that influence the effectiveness of AR integration within the education system, including pedagogical factors, infrastructure, teacher competency, and student readiness.
4. To analyse the key challenges faced in the implementation of AR technology in education and to propose appropriate solutions to ensure its effectiveness and sustainability at the national level.

III. Methodology

This research employs a Systematic Literature Review (SLR) approach to examine various studies involving the use of Augmented Reality (AR) technology within the educational context in Malaysia. This approach was chosen as it allows for a more comprehensive and objective evaluation of existing literature while also identifying trends, patterns, and research gaps related to the effectiveness and challenges of AR implementation in the national education system. Accordingly, specific steps were undertaken based on the five phases proposed by Khan, Khunz, Klenijnen, and Ante (2003). The five phases are: framing the research questions, identifying relevant studies, assessing the quality of the studies, summarising the evidence, and interpreting the findings as illustrated in Figure 1 below.

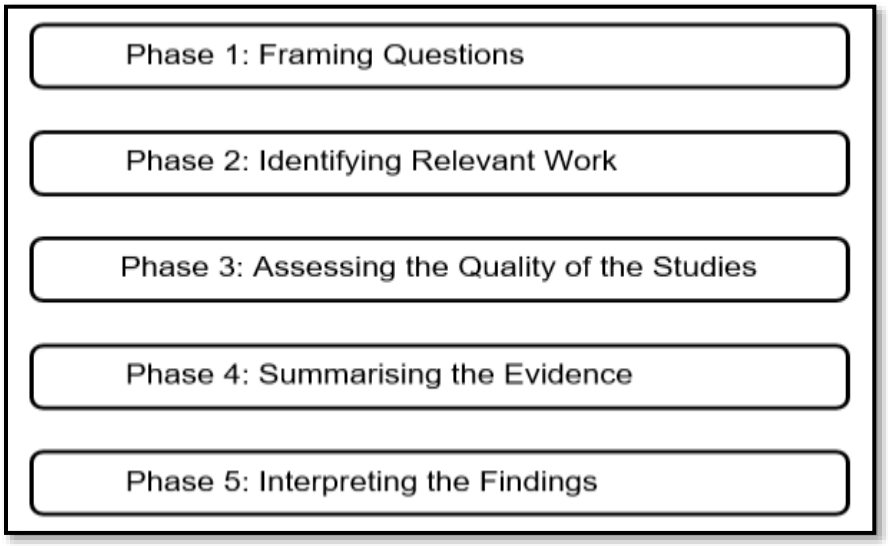

***Figure*1**. Phases of the Systematic Literature Review

3.1.Phase 1: Framing the Research Questions

Education in the digital era highlights the use of technology as a crucial element in producing digitally fluent learners and fostering students' interest in learning. The use of Augmented Reality (AR) has increasingly been emphasised in the teaching and learning process to enhance students' mastery while also creating engaging learning experiences. This research aims to explore the application of AR technology in Malaysian education. Four research questions have been formulated to guide the research:

1. What is the level of usage and acceptance of Augmented Reality (AR) across various educational contexts in Malaysia?
2. To what extent is AR effective in enhancing student learning outcomes across different disciplines and educational levels?
3. What are the factors that influence the effectiveness of AR integration in education?
4. What are the challenges and potential solutions in implementing AR within the Malaysian education system?

3.2.Phase 2: Identify Relevant Work

The article search was conducted using databases such as Google Scholar, Web of Science, and Scopus. Most articles were retrieved from Google Scholar due to its accessibility to full-text documents whereas Web of Science and Scopus posed certain limitations in accessing relevant articles. Keywords such as "Augmented Reality in Malaysian education," "use of AR in learning," "effectiveness of AR in the classroom," and "augmented reality in

education" were employed to facilitate the search for literature pertinent to the research's topic. The search results from Google Scholar, Web of Science, and Scopus included journals, theses, conference proceedings, and literature reviews. The articles obtained were selected based on predetermined inclusion and exclusion criteria.

3.3.Phase 3: Assessing the Quality of the Studies

The selected articles were required to meet specific inclusion and exclusion criteria. The search period for articles related to AR in the Malaysian education landscape was set from 2020 to 2024 to ensure that all studies included are current and relevant to the present educational context in Malaysia. The inclusion and exclusion criteria used for article selection are outlined in Table 1.

Table1 . Inclusion and exclusion criteria

Criteria	Inclusion	Exclusion
Type of Research	● Conducted within the context of education in Malaysia ● Explicitly involves the use of AR technology in the teaching and learning process ● Empirical studies using either quantitative, qualitative, or mixed-methods approaches ● Full-text access is available	● Studies not based in the Malaysian educational context ● Does not involve direct use of AR technology ● Conceptual articles without empirical data ● Duplicate or incomplete articles
Language	● Articles written in Malay or English	● Articles not written in Malay or English
Search Period	● Published within the last five years (2020–2024)	● Articles published before the year 2020

3.4.Phase 4: Summarising the Evidence

As a result of the initial search, a total of 99 articles were identified where 32 articles are from *Google Scholar*, 37 articles from *Web of Science*, and 30 articles from *Scopus*. Each article underwent a systematic screening process, starting with the review of titles and abstracts followed by a full-text review based on the predetermined inclusion and exclusion criteria. After a thorough evaluation of the methodology and relevance of the content, only 20 articles met all criteria and were selected for detailed analysis in this research. These selected articles represent various disciplines and educational levels, thus providing a comprehensive overview of the use of AR in Malaysian education. The article selection process is illustrated in Figure 2 below.

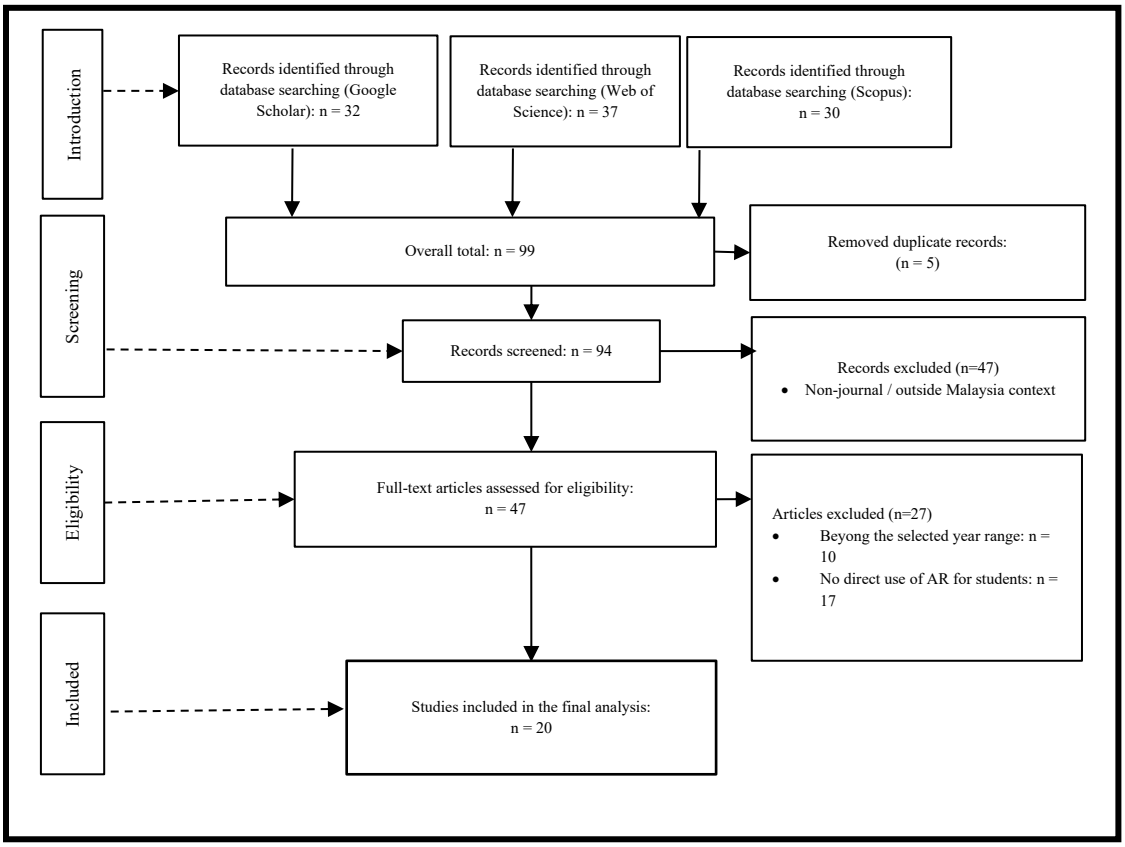

Figure 2. Article selection flowchart

3.5.Phase 5: Interpreting the Findings

A total of 20 articles were selected for in-depth analysis. Of these, 9 articles sourced from Google Scholar employed a quantitative research design, 1 article adopted a qualitative approach, while 5 articles utilised a mixed-methods design. All four articles obtained from the Web of Science database were quantitative in nature with no qualitative or mixed-methods studies identified. Only one article was selected from the Scopus database which also employed a quantitative design. Table 2 presents the distribution of research designs according to the respective databases of Google Scholar, Web of Science, and Scopus.

Table 2. Research design

Research Design	**Database**		
	Google Scholar	***Web of Science***	***Scopus***
Quantitative	9	4	1
Qualitative	1	0	0
Mixed Method	5	0	0
Total	**20**		

Summary of the studies reviewed in this literature synthesis including the authors' names, research titles, levels of education, subjects investigated, research methodologies, and key findings is presented in Table 3 below.

Table 3.Summary of the studies involved

No	Author(s), Year and URL	Title of the Study	Educational Level	Field/Subject	Methodology	Summary of Findings
1.	Mohd Hanif Jofri et al. 2022 https://shorturl.at/kH9kq	ARnotomy: Primary School Science Learning Application	Primary School	Science	• Design: Quantitative study • Instruments: Questionnaire and observation • Sample: 17 primary school pupils and 3 teachers	AR enhances students' understanding and interest in Science
2.	Haliza Idris et al. 2022 https://shorturl.at/6Uhw2	The effectiveness of AR in the topic of Early Mathematics Patterns	Early	Mathematics	• Design: Mixed-method • Instruments: Checklist, evaluation form, observation, and questionnaire • Sample: Preschool teachers and pupils	AR increases students' interest and understanding, and encourages parental and teacher involvement
3.	Nurul Hafiza Mohd Pozi & Wan Shazlina Wan Ismail 2022 https://short-link.me/13xjL	Easy Huayu: Mandarin for Beginners uses AR	Early/ General	Mandarin Language	• Design: Mixed-method • Instruments: Questionnaire, observation, and content analysis • Sample: Secondary school students, tertiary students, and adults aged 17–35	AR is effective in assisting language learning through interactive multimedia
4.	Khairuddin Abd Rahman &Noor Dayana Abd Halim 2024 https://short-link.me/13xk1	AR & inquiry-based learning for spatial reasoning	Year 3	Mathematics	• Design: Quantitative study • Instruments: Spatial reasoning test • Sample: 25 Year 3 pupils	AR improves spatial reasoning and student interest
5.	Ganesh Mukayah, Rossseni Din 2021 https://short-link.me/-tlF	AR-enabled reading proficiency in Tamil	Year 4	Tamil Language	• Design: Quantitative study • Instruments: Pre-test and post-test, questionnaire, checklist	AR improves reading skills and increases student interest

					• Sample: 30 Year 4 pupils	
6.	Lillyshallini & Nor Azwahanum 2024 https://shorturl.at/cfpOe	Proficiency in composing Malay paragraphs using AR	Year 3	Malay Language	• Design: Qualitative study • Instruments: Structured and unstructured observation, pre-test, post-test • Sample: 3 Year 3 pupils	AR helps mastery of grammatical writing skills
7.	Farah Waheda Othman et al. 2024 https://short-link.me/-tlS	AR-MicroC Module in Technical Education	Community College	Information Technology	• Design: Quantitative study • Instruments: Achievement test • Sample: 66 students from four Community Colleges	AR improves student achievement in IoT courses
8.	Goh Chin Shuang et al. 2024 10.7176/JEP/14-33-12	AI and AR integration in Mandarin language instruction	Higher Education	Mandarin Language	• Design: Quantitative study • Instruments: Questionnaire • Sample: 238 UiTM students	AR-AI aids basic language understanding and reduces cognitive load
9.	Haliza Idris et al. 2022 https://rb.gy/aqmw6x	The EM-Flip module uses AR in Early Mathematics	Preschool	Mathematics	• Design: Mixed-method • Instruments: Questionnaire and document analysis • Sample: Teachers, parents, and students	Flipped classroom with AR encourages active student participation
10.	Azam Abd Aziz et al. 2024 https://rb.gy/8z4ef1	Stage of knowledge & acceptance of AR in SBP	Secondary School	General	• Design: Quantitative study • Instruments: Questionnaire • Sample: 370 lower secondary school students	High level of student knowledge and acceptance of AR
11.	Mohamad Roshaiqal & Mohd Norasri 2021 https://rb.gy/ldo1b5	Learning letters using AR	Kindergarten	Language	• Design: Quantitative study • Instruments: Functionality test • Sample: 10 target users	AR promotes interactivity and has high usability scores

12.	Ong Shu Wei& Faridah Mydin Kutty 2022 https://short-link.me/-tm8	Motivation & engagement of remedial students in writing through AR	Year 2 (Remedial)	Malay Language	• Design: Mixed-method • Instruments: Evaluation test, questionnaire, and interview • Sample: 4 Year 2 remedial pupils	AR increases motivation and involvement in writing activities
13.	Fadilah Abdul Rauf et al. 2022 https://rb.gy/z1wifc	The potential of AR in preschool colouring activities	Preschool	Creativity	• Design: Quantitative study • Instruments: Checklist • Sample: 10 preschool pupils	AR enhances creative thinking and fluency
14.	Yogalakshimi & Aidah 2024 https://short-link.me/-tli	Interest & knowledge in Science through AR	Preschool	Science	• Design: Mixed-method • Instruments: Checklist, interview, exercise book tests, and brain teasers • Sample: 12 preschool children and 1 teacher	AR helps attract interest and increases children's knowledge
15.	Dhivagar Gunalan & Rosseni Din 2023 https://rb.gy/xh1lik	Topic: Food Digestion with AR	Year 3	Science	• Design: Quantitative study • Instruments: Interview and usability test • Sample: 5 Year 3 pupils and 5 teachers	AR improves student achievement and increases teacher interest
16.	Kartigeyan Saundarajan et al. 2020 https://short-link.me/-tky	Learning Algebra Using Augmented Reality	Form 2	Mathematics	• Design: Mixed-method • Instruments: Pre-test, post-test, and questionnaire • Sample: 33 lower secondary students	AR (Photomath) improves algebra learning performance; students' confidence and readiness with Photomath is moderate
17.	Nadzri et al. 2023 https://short-link.me/13xis	Implications of AR Modules on Geometry Conceptual and	Year 4	Mathematics	• Design: Quantitative study • Instruments: Pre-test, post-test, and delayed post-test	AR enhances conceptual and procedural knowledge in geometry

		Procedural Knowledge among Primary School Students			• Sample: 29 experimental group, 30 control group	
18.	Nurul Amelina Nasharuddin 2021 https://short-link.me/-tkP	A Preliminary Investigation on Learning Basic Chemistry using Virtual Reality	Secondary School Students	Chemistry	• Design: Quantitative study • Instruments: Questionnaire • Sample: 5 students	Students show positive feedback toward *prototype* application in basic Chemistry
19.	Syed Zuhairy Syed Sazly et al. 2021 https://short-link.me/-tkS	Development of Augmented Reality Applications in Teaching and Learning for a topic of Current and Voltage Division for Technical and Vocational Education	Bachelor of Technology with Education	Electric and Electronics	• Design: Quantitative study • Instruments: Questionnaire • Sample: 73 students in the Electrical and Electronic Education Program	AR applications are engaging and user-friendly for learning about Current and Voltage Division
20.	Jehan Adiba Binti Ahmad Taha et al. 2024 https://short-link.me/13xjT	Effectiveness of Using Augmented Reality Application in the Subject of Educational Technology for Undergraduate Students	UTM Undergraduate Students	Educational Technology	• Design: Quantitative study • Instruments: Pre-test, post-test, and questionnaire • Sample: 56 Technology Education students	Students using AR apps recorded higher academic performance than control group (traditional method); students had a positive perception toward AR

IV. Research Findings

Data analysis was conducted using a thematic analysis approach whereby the selected studies were coded and categorized into four main themes: (i) the level of AR usage and acceptance, (ii) the effectiveness of AR on learning outcomes, (iii) factors influencing the integration of AR, and (iv) challenges and proposed improvements in its implementation. This section elaborates on the key findings derived from the analysis of previous studies related to the use of Augmented Reality (AR) in the Malaysian education context. The findings indicate that AR has been applied across various educational levels, including early childhood education, preschool, primary school, secondary school, and higher education. Six articles highlighted the use of AR in early childhood education while seven studies explored its implementation at the primary school level. These findings clearly demonstrate that AR plays a significant role in shaping understanding and conceptual development in early childhood education.

Moreover, three articles examined the implementation of AR at the secondary school level while four studies explored the use of AR in higher education. Based on the summary of these studies, it can be concluded that research involving the use of AR in early childhood and primary education has dominated this systematic review. The introduction of learning concepts at an early stage is crucial to prevent the formation of misconceptions about subject matter, to facilitate pupils' understanding of these concepts, and to reduce the risk of conceptual misunderstandings. (Mohd Hanif Jofri et al.; Haliza Idris et al., 2022).

The use of Augmented Reality (AR) extends not only across various educational levels but is also widely applied in multiple fields and subjects within the Malaysian education system. Overall, AR has been integrated into language education, the arts, science and mathematics subjects including chemistry as well as in information technology and electrical courses offered at community colleges. Articles investigating the use of AR in language learning include those related to the Malay language, Mandarin, and Tamil. The integration of AR in language learning has been shown to enhance pupils' language proficiency, support writing skills development, and facilitate foundational language comprehension while reducing learners' cognitive load (Ganesh Mukayah & Rosseni Din, 2021; Goh Chin Shuang, Hao Yixuan & Airil Haimi Mohd Adnan, 2024).

The application of AR in the arts field has also been shown to significantly enhance students' creativity (Fadilah Abdul Rauf & Tan Wee Hoe, 2020). In Science and Mathematics subjects, AR plays a crucial role in building conceptual understanding, enhancing reasoning skills, and expanding students' knowledge in the respective domains (Letchumanan & Karim, 2024; Khairuddin Abd Rahman & Noor Dayana Abd Halim, 2024). At the higher education level, the integration of AR holds the potential to improve students' academic performance in various courses. Tertiary students have also expressed positive feedback towards the use of AR applications especially when learning complex topics that are otherwise difficult to comprehend. In summary, the implementation of AR has proven to be effective and impactful across multiple learning domains, contributing positively to students' motivation, interest, and academic achievement. The subsequent sections will further discuss the findings in relation to the four research questions established in this systematic literature review.

4.1. Objective 1: The Level of Use and Acceptance of AR in Education

Findings from the analysis indicate that the use of Augmented Reality (AR) in Malaysian education is steadily growing particularly among educators at the preschool and primary school levels. A research by Azam Abd Aziz, Norzalilah Mohamad Mazli, Noor Amera Omar, and Mohd Jasmy Abd Rahman (2024) found that students demonstrate a high level of knowledge and acceptance toward AR technology. Similarly, studies by Mohd Hanif Jofri et al. (2022), Ganesh Mukayah and Rosseni Din (2021), Nurul Amelina Nasharuddin (2021), and Syed Zuhairy Syed Sazly et al. (2021) reported that AR applications were well-received by both students and teachers. Furthermore, research by Jehan Adiba Binti Ahmad Taha et al. (2024) revealed that students enrolled in the Educational Technology program held favourable and positive perceptions of using AR applications in the subject of Educational Technology. This positive reception is influenced by the user-friendliness of AR applications, increased access to mobile devices, and strong support from teachers during implementation.

4.2. Objective 2: The Effectiveness of AR in Enhancing Learning Outcomes

A significant number of studies have demonstrated the effectiveness of Augmented Reality (AR) in improving students' academic achievement and conceptual understanding. For instance, research by Gunalan Mukatah and Rosseni Din (2023) found that the use of AR materials in the topic of food digestion enhanced the performance of Year 3 pupils. Similarly, Khairuddin Abd Rahman and Noor Dayana Abd Halim (2021) reported a notable improvement in students' spatial reasoning following an AR intervention. A research by Haliza Idris et al. (2022) also indicated an increase in students' interest and engagement when learning mathematical patterns. Furthermore, research by Kartigeyan Saundarajan, Sharifah Osman, Mohd Fadzil Daud, Mohd Salleh Abu, and Mohamad Rasidi Pairan (2020) validated the effectiveness of the AR application *Photomath* in improving students' performance in algebra. Nadzri et al. (2023) found that AR enhanced pupils' conceptual and procedural knowledge in geometry. Meanwhile, a research by Jehan Adiba Binti Ahmad Taha et al. (2024) confirmed the effectiveness of AR in boosting academic achievement in the subject of Educational Technology.

4.3. Objective 3: Factors Influencing the Effectiveness of AR Integration

The factors contributing to the effective integration of Augmented Reality (AR) can be categorised into four main areas: (i) the pedagogical approach employed, (ii) the usability of the application, (iii) the design of interactive content, and (iv) the role of the teacher. Nurul Hafiza Mohd Pozi (2022) and Lillyshallini Chandran and Nor Azwahanum Mohd Said (2024) emphasised the importance of user-friendly and engaging application design. Additionally, the research by Haliza Idris et al. (2022), which adopted the TUP Model demonstrated that the technological, usability, and pedagogical components must be well-balanced to ensure the successful implementation of AR in education.

4.4. Objective 4: Challenges and Solutions in the Implementation of AR

Three primary challenges have been identified in the implementation of Augmented Reality (AR) in education which are (i) limitations in technological infrastructure, (ii) insufficient training for teachers, and (iii) dependence on specific devices such as smartphones or tablets. The research by Ong Shu Wei and Faridah Mydin Kutty (2022) revealed that although AR enhances the motivation of remedial students, teachers face difficulties in preparing appropriate materials and applications. As a solution, Letchumanan and Karim (2024) proposed providing AR technology training to preschool teachers, while Rosman and Ismail (2021) recommended the use of markerless AR to facilitate easier user access.

V. Discussion of Findings

The discussion in this section addresses the four main research questions, while also relating the findings to previous literature and evaluating their implications for the field of education in Malaysia.

5.1. The Level of Use and Acceptance of AR in Education

The adoption and acceptance of Augmented Reality (AR) technology within Malaysia's education system remain in the early stages, but show a positive upward trend. Based on the analysis of 20 selected studies, the majority indicate that AR is currently employed on a small scale, typically within specific instructional modules or educational innovations particularly in the context of action research, application development, and focused teaching. The use of AR is not yet mainstreamed but is predominantly implemented by educators engaged in research projects or teaching innovations. This indicates that AR integration has yet to become widespread in the national education system. For instance, the research by Mohd Hanif Jofri et al. (2022) involving the use of the ARnotomy application in primary school Science classes highlights efforts by educators to introduce visual and interactive learning approaches with AR functioning as a supportive learning tool. The application received positive feedback from both students and teachers due to its engaging and interactive content. Similarly, in a research by Ganesh Mukayah and Rosseni Din (2023)

focusing on the Tamil language, Year 4 students demonstrated increased motivation and interest in reading after engaging with the AuRa-BT module. These studies suggest that, even within limited subject areas and school settings, AR has the potential to enhance student engagement effectively.

The research by Nurul Amelina Nasharuddin (2021) revealed that secondary school students responded positively to the use of a *prototype* application for learning basic Chemistry. The application's integration of appropriate quiz questions, realistic 3D models, and visually appealing design contributed to its effectiveness. Similarly, research conducted by Syed Zuhairy Syed Sazly et al. (2021) reflected a favourable reception among students enrolled in the Technology in Education course towards the use of AR in learning topics such as Current and Voltage Division. The positive acceptance in both studies was attributed to the interactive and user-friendly design of the applications, underlining the importance of engaging design elements in enhancing user receptivity to AR. In addition, the research by Jehan Adiba Binti Ahmad Taha et al. (2024) showed that students from the Educational Technology Programme held positive and constructive perceptions of AR applications in the subject of Educational Technology. This acceptance was influenced by students' high levels of knowledge about AR applications, their confidence in the technology's effectiveness, and the ease and efficiency with which AR could be incorporated into the learning process. Positive acceptance of AR was also evident in the research by Azam Abd Aziz, Norzalilah Mohamad Mazli, Noor Amera Omar, and Mohd Jasmy Abd Rahman (2024), which demonstrated that students in Full Boarding Schools (Sekolah Berasrama Penuh – SBP) exhibited high levels of knowledge and acceptance of AR. Using a questionnaire-based approach involving 370 lower secondary students, the research identified a significant relationship between students' knowledge levels and their acceptance of AR technology. This finding reflects a readiness among students to embrace more interactive learning methods, in alignment with the advances of the Fourth Industrial Revolution (IR 4.0).

Nevertheless, from a dissemination perspective, the use of Augmented Reality (AR) in education remains concentrated within specific regions or among individual educators who are personally proactive, rather than resulting from a comprehensive national education policy. Most teachers who integrate AR into their teaching do so as part of action research or instructional innovation projects (Ong Shu Wei & Faridah Mydin Kutty, 2022; Chandran & Said, 2024). Constraints such as limited professional training, high content development costs, and uneven digital infrastructure continue to pose significant challenges to the systematic integration of AR in classrooms. Overall, although the widespread adoption of AR in education is still at a nascent stage, the level of acceptance among both students and teachers is highly encouraging. This indicates a promising potential for future expansion, provided it is supported by robust educational policies, targeted professional development, and the enhancement of technological infrastructure.

5.2. Effectiveness of AR in Enhancing Learning Outcomes

Findings from the reviewed studies demonstrate that Augmented Reality (AR) has a significant impact on improving students' learning outcomes across cognitive, affective, and psychomotor domains. This is evident through increased student scores in pre- and post-tests, heightened motivation and engagement, and reduced cognitive barriers in understanding abstract concepts. For instance, in the research by Gunalan Mukatah and Rosseni Din (2023) on the topic of food digestion for Year 3 pupils, students exhibited improved academic scores after using a custom-developed AR module. Teachers also reported that students were more focused and actively engaged throughout the learning session. This suggests that the integration of visual media, interactivity, and immersive learning experiences can enhance students' comprehension of abstract scientific concepts. Similarly, the research by Jehan Adiba Binti Ahmad Taha et al. (2024) confirmed the effectiveness of AR in improving academic achievement in the subject of Educational Technology. The research revealed a significant difference in scores between the experimental group using AR applications and the control group using conventional methods. Students agreed that AR increases their motivation and interest in exploring complex topics and allows for more active involvement in the learning process through the use of three-dimensional visualisation and multimedia elements embedded in the AR application.

The research by Khairuddin Abd Rahman et al. (2024) demonstrated the effectiveness of Augmented Reality (AR) in enhancing spatial reasoning among Year 3 students in the Mathematics topic of Space. Students showed a mean score increase of 6.16 points in the post-test and the findings revealed a statistically significant difference between the pre- and post-intervention assessments. This indicates that AR can support students in developing their understanding through learning that involves visualisation and manipulation of three-dimensional objects. The effectiveness of AR in the field of Mathematics is also evident in the research conducted by Kartigeyan Saundarajan et al. (2020), which confirmed that the AR application Photomath effectively improved students' performance in learning algebra. The application aided students in understanding and solving algebraic problems with ease. Similarly, the research by Nazdzri et al. (2023) found that AR-based modules enhanced both conceptual and procedural knowledge in the topic of geometry. These studies, which focus on the domain of Mathematics collectively provide compelling evidence that AR facilitates student learning particularly by supporting the development of conceptual understanding and assisting students in solving complex problems through the use of AR-based modules and supportive applications.

On the other hand, in the field of language education, studies by Nurul Hafiza Mohd Pozi and Wan Shazlina (2022), as well as Goh Chin Shuang, Hao Yixuan, and Airil Haimi Mohd Adnan (2024), demonstrated that non-native speakers were able to grasp the fundamentals of the Mandarin language through learning experiences that integrated multimedia elements and Augmented Reality (AR). The use of text, audio, and images via the *Easy Huayu* application enriched the learning experience, making it more engaging and thereby facilitating memory retention and language acquisition. Furthermore, a research by Lillyshallini Chandran and Nor Azwahanum Mohd Said (2024) on grammatical writing skills in the Malay language found that AR supported pupils in understanding sentence structures more effectively through visual and interactive approaches. In the preschool context, the research by Fadilah Abdul Rauf and Tan Wee Hoe (2020) reported a significant improvement in children's creative thinking and fluency after participating in colouring activities that utilised AR technology. These findings suggest that AR is not only suitable for formal education at the primary and secondary levels but can also be adapted for play-based learning in early childhood education. In conclusion, AR has been proven to enhance student learning outcomes across various educational levels and disciplines including science, mathematics, language, and technical education. Its effectiveness depends largely on the appropriateness of instructional design, the interactivity of the materials, and the pedagogical strategies employed alongside the technology.

5.3. Factors Influencing the Effectiveness of AR Integration in Education

The effectiveness of integrating Augmented Reality (AR) technology in education does not rely solely on the availability of the technology itself; rather, it is influenced by a range of internal and external factors that either facilitate or impede its implementation. Based on the analysis of 20 studies, several key determinants have been identified which are pedagogical design, the digital literacy levels of educators, the suitability of devices and infrastructure, and the design quality of the AR content. Among these, a comprehensive pedagogical design stands out as a critical factor. A research by Haliza Idris et al. (2022), which employed the TUP Model (Technology, Usability, Pedagogy), underscores that the successful implementation of AR is achievable only when all three components are integrated in a balanced and coherent manner. Advanced technology alone does not ensure effective learning outcomes if it is not supported by appropriate pedagogical strategies and learner-friendly, accessible content.

The design of instructional content plays a critical role in ensuring that AR effectively supports the learning process. Studies by Nurul Hafiza Mohd Pozi et al. (2022) and Mohamad Roshaiqal Ameen Rosman and Mohd Norasri Ismail (2021) demonstrated that interactive multimedia elements in applications such as *Easy Huayu* and *ABC Realiti Terimbuh* are capable of capturing users' attention, making the learning experience more engaging and memorable. Three-dimensional content, animations, audio, and interactive features offer significant advantages in helping students comprehend complex concepts, such as the structure of the human body, letters, or foreign vocabulary. Equally important is the capability and readiness of teachers. Although most studies indicate a high level of student interest in

AR, its effectiveness can only be fully realised when teachers possess the necessary understanding and skills to effectively integrate and adapt this technology into their teaching. As highlighted in the research by Chandran and Said (2024), the effectiveness of AR applications in enhancing students' writing skills was only achieved because the teacher implemented focused instruction supported by appropriate observation and assessment techniques.

Lastly, the suitability of infrastructure and devices also significantly influences the success of AR implementation in education. A research by Farah Waheda Othman, Irdayanti Mat Nashir, Mohamad Syahril Mat Saad, Nor Roselidyawaty Mohd Rokeman, and Muhamad Asrul Affendi Mat Nor (2024), which involved Community College students using the AR-MicroC module in the field of IoT, found that the availability of equipment such as smartphones and laboratory facilities is crucial to ensuring smooth implementation. If an institution lacks access to appropriate devices or a stable internet connection, the effectiveness of AR may be hindered. Overall, the effectiveness of AR in education is highly dependent on the synergy between technology, content, pedagogy, and environmental support. Only through the integration of these factors can AR be implemented in a manner that delivers maximum impact on student learning.

5.4. Challenges and Solutions in the Implementation of AR in the Malaysian Education

Despite the tremendous potential of Augmented Reality (AR) in education, its implementation within the Malaysian context faces a range of practical and systemic challenges. Based on the analysis of various studies, several key issues have been identified: (i) infrastructure and resource limitations, (ii) lack of professional training and support for teachers, (iii) difficulties in content development, and (iv) time constraints and institutional readiness. Infrastructure and resource limitations represent the most fundamental challenge. AR requires appropriate mobile devices, stable internet connectivity, and learning environments that support the integration of such technology. A research by Mohamad Roshaiqal Ameen Rosman and Mohd Norasri Ismail (2021) found that the use of AR applications dependent on physical markers (marker-based AR) can be a constraint if the necessary materials are difficult to obtain or costly. In fact, the research recommends the development of markerless AR technology to enhance user-friendliness and accessibility.

A lack of training and support for teachers also constitutes a major challenge. As discussed by Ong Shu Wei and Faridah Mydin Kutty (2022), although AR has the potential to enhance motivation and engagement among remedial learners, teachers face difficulties in producing and adapting suitable instructional materials. Without access to professional training or workshops, educators risk using AR in a superficial manner without fully understanding its pedagogical potential. Content development poses another significant barrier. AR content creation is inherently complex, often requiring programming skills, 3D graphics, and animation. The research by Mohd Hanif Jofri et al. (2022), for instance, required the use of SDKs, Unity, and Vuforia, tools that many teachers are not proficient in. Therefore, collaboration between teachers and educational technology experts is crucial to ensure the effective integration of AR into teaching and learning practices.

From a solution-oriented perspective, the research by Letchumanan and Karim (2024) recommends that schools and the Ministry of Education provide targeted training for teachers to enable them to effectively plan, implement, and evaluate the use of AR in teaching and learning. In addition, collaboration between industries, universities, and educational institutions is encouraged to develop ready-to-use (plug and play) AR learning modules, thereby facilitating ease of use for teachers at all levels. Furthermore, national digital education policies such as those outlined in the Malaysian Education Development Plan (PPPM) 2013–2025 should integrate immersive technologies like AR in a more comprehensive manner, rather than treating them as supplementary components. This would provide a solid foundation for building a sustainable and inclusive digital education ecosystem.

VI. Conclusion

This research conducted a systematic literature review of 20 studies related to the use of Augmented Reality (AR) technology in education in Malaysia between the years 2020 and 2024. The objective of this review was to identify the level of use and acceptance of AR, evaluate its effectiveness on learning outcomes, determine the factors influencing its integration, and explore the challenges and solutions associated with its implementation within the national education system. Overall, the findings indicate that the use of AR in Malaysian education is steadily growing and is well-received by both students and teachers. Although its application is not yet widespread and remains largely concentrated in innovation projects or action research, the positive reception suggests that this technology holds significant potential for broader development and adoption in the future.

The effectiveness of AR in enhancing student learning outcomes has been demonstrated across various approaches and subject areas. Whether in Science, Mathematics, Languages, or Technical Education, AR plays a significant role in making learning more interactive, engaging, and impactful. It also contributes to the development of cognitive skills such as spatial reasoning, creativity, and effective language acquisition. However, the success of AR implementation is influenced by several critical factors, including pedagogical design, technological usability, teacher competency, and the quality of learning content. The absence of these factors can diminish the potential impact of AR even when the necessary equipment is available. Therefore, successful implementation requires a holistic approach encompassing teacher training, infrastructural support, and system readiness.

The implementation of AR in Malaysian education also faces various challenges, including infrastructural constraints, lack of training, and difficulties in content development. Addressing these issues requires continuous support from multiple stakeholders such as the Ministry of Education Malaysia, institutions of higher learning, and local technology industries in developing AR modules that are user-friendly, high-impact, and accessible. As a future recommendation, stakeholders are encouraged to develop dedicated policies on immersive technologies in education, provide teacher training programmes focused on the use of AR, and establish strategic collaborations between educators and technology developers to produce learning materials aligned with the national curriculum. This review presents a comprehensive overview of AR's potential as a future pedagogical tool in Malaysian education. With strategic planning and structured implementation, AR can support the digital transformation of education towards a more innovative, inclusive, and competitive system in the era of the Fourth Industrial Revolution.

VII. Limitations of The Research

This research analysed only 20 articles related to the use of Augmented Reality (AR) in education within the Malaysian context. This limitation arose due to time constraints and the reliance on a limited number of search databases, namely Google Scholar, Web of Science, and Scopus. Additionally, the research faced challenges in accessing sources that required subscription or payment to obtain the full articles. Therefore, future research will aim to expand the range of databases to include platforms such as ERIC and MyJurnal in order to increase the number of articles available for analysis and provide a more comprehensive exploration of the research topic.

VIII. Implications of The Research

This research provides valuable insights for educators on the effectiveness and potential of Augmented Reality (AR) in enhancing student achievement and motivation. With this knowledge, educators can incorporate AR applications into their teaching practices to improve the quality of education. This research also raises awareness among school administrators to assess the level of AR usage in their respective schools in order to optimise its integration in the teaching and learning process. Furthermore, the findings may serve as a reference for the Ministry of Education Malaysia (MoE) to design pedagogical training for educators, provide technological support, and allocate financial resources to strengthen the implementation of AR in education. The challenges identified in this research offer a comprehensive perspective for relevant stakeholders to reassess the current state of the education system and implement appropriate interventions to ensure the smooth integration of AR technology in Malaysian education.

Based on the findings of this research, future research could explore the use of Augmented Reality (AR) among teachers in rural schools. Researchers may examine the extent of AR integration and the challenges faced by educators in applying AR within teaching sessions in these contexts. In addition, subsequent studies could investigate the implementation of AR in language education, focusing on its effectiveness in enhancing language learning in a more in-depth and nuanced manner. The current research reveals that AR usage in education remains at an early stage, primarily concentrated on instructional innovation and prototype development. Therefore, future research could focus on the design and evaluation of AR applications that align with curriculum content and learners' needs across various educational levels. Researchers may also assess teacher-developed AR models and their effectiveness in supporting student learning.

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