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Malaysian STEM Teachers' Acceptance, Readiness and Challenges in Implementing Augmented Reality (AR) Tools in Teaching Science

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ABSTRACT

The application of augmented reality (AR) is progressively becoming well-known as a powerful pedagogical means for the learning of science since it overcomes the limitations of traditional pedagogy, including lack of adequate visualization of abstract concepts, lack of student interest and participation, and the capacity to understand complex concepts. This study therefore explored STEM teachers' acceptance, readiness, and challenges in implementing AR, focusing on a district of Selangor. Utilizing a quantitative approach, data were collected using a structured questionnaire given to 100 secondary school STEM teachers via purposive sampling. Findings revealed that the teachers exhibited low to moderate acceptance ($M = 2.18–2.72$) and readiness ($M = 2.19–2.51$). The significant issues were insufficient training, limited resources, and insufficient time. A One-Way ANOVA revealed significant discrepancies in teachers' readiness across different years of teaching experience ($F (2,97) = 18.161$, $p < 0.001$). The presence of an extremely strong positive correlation between acceptance and readiness ($r = 0.900$, $p = 0.000$) also validated their interdependence. In general, the study indicates the need for targeted professional development, organizational support, and resource provision to facilitate the integration of AR in science education. Future studies would likely extend scope to include other subject teachers such as Islamic education, humanities, and the arts.

Keywords: Augmented reality, Acceptance, Readiness, Challenges, Teaching experience

INTRODUCTION

The education in Malaysia has undergone various transformations due to the necessity to prepare young generations who possess the qualities to face the challenges of the 21 st century (Mukhtar & Fook, 2020). Numerous programs have been established under the Malaysian Education Blueprint (MEB) designed to improve the teaching and learning process's quality and effectiveness. These programs are motivated by the fact that the conventional chalk and talk method of teaching and the use of printed textbooks are ineffective and unable to engage students which ultimately lead to inferior learning outcomes. The curriculum transformation (Shift 7: Leverage ICT to scale up quality learning across Malaysia) which entails the initiatives to improve the use of ICT in the educational system has widen the possibilities of using technological tools for teaching and learning (MOE, 2013). Under this shift, the government is committed provided large sums of money to clearly enhance teacher competency through different policies and professional development programs, which would help teachers to reorganize instruction to meet the needs of students more effectively. (Kin & Kareem, 2019). Teachers with these competencies will be more capable of enhancing learning achievements and creativity for students to become innovative due to the fact that they are technologically literate and aware that change is inevitable, progressive, and beneficial rather than destructive. (Panagiotopoulos & Karanikola, 2020).

In its early stages, learning relied on manuscripts before progressing to printed textbooks and later to digital editions. However, the transition to digital textbooks has not yielded significant benefits for either students or teachers, largely due to the absence of interactive elements (Alfiras & Bojiah, 2020). Traditional Teaching and Learning (PdPc) approaches are now seen as insufficient for preparing learners to confront future demands. Therefore, integrating technology into PdPc is essential to ensure that students are equipped with the competencies required in the 21st century (Safri & Jamaludin, 2022). Technology is a wonderful asset that transforms education in many ways. For instance, technologies make it possible for individuals to study and collaborate in a unique way. Also, with the availability of smart devices that can be made connectable to the internet, there has been a revolution which makes learning possible at any given time. It is high time that teachers start utilizing their technological potential towards better classroom learning and teaching procedures. This is because the students are curious and they enjoy finding things out as they learn. This is why mobile phones and other mobile devices are increasingly on demand with students. Thus, teachers are required to think innovatively while conducting classes and they must make learning a fun experience for students using technology in teaching and learning. The use of technology in education is not something new, especially with the learning and teaching platform of the 21st century (Ziden et al., 2022).

Science is a vital discipline that requires continuous attention due to its level of complexity, and incorporating technology within science education serves as an important role in clarifying abstract concepts. By leveraging technology, students are believed to not only enhance their learning experiences but also develop critical and creative thinking skills. The use of information and communication technology (ICT) in schools, therefore, expands opportunities for more engaging and rewarding learning experiences (Fitriyadi, 2015). However, previous studies have shown that many students have difficulty to grasp core science concepts, including biology, chemistry, and physics (Nordin & Ling, 2011). Most of the students also have unfavorable attitudes towards science due to the belief that it is hard, complex and not easy to understand (Nordin & Ling, 2011). Based on Awang (2015), one contributing factor is the absence of quality learning media that can simulate real-life situations. Besides this, students are also weak in developing science process skills in an integrated manner and cannot integrate these skills (Anggara et al., 2021). Thus, the reality is revealed that students fail to understand scientific processes if there is no additional instructional and learning assistance. Thus, incorporating technology in science instruction can possibly provide learning experiences that are more engaging and significant.

The advancement of technology has led to the emergence of augmented reality (AR), which is seen as a valuable tool in supporting student learning, particularly for those with lower spatial visualization abilities (Uribe et al., 2023). AR is the projection of virtual reality such as images, texts, videos, and sounds on a screen in order to offer an augmented visual experience (Hussein, 2022; Jafari et al., 2023). That is, placing virtual information on digital tools in a bid to stimulate real-world experiences (Lo et al., 2021). Moreover, it is one of the new technologies that can be applied in learning and teaching processes because it employs various mobile devices such as smartphones and tablets (mobile AR) since they are affordable and simple to operate for AR (Furió et al., 2013). In education, AR is not only regarded as a medium for delivering instructional content but also as a means of enhancing students' achievement, especially in science subjects (Bogomolova et al., 2019; Sahin & Yilmaz, 2020). Furthermore, it allows students to engage with complex topics in an enjoyable and accessible environment through virtual devices (Yildiz, 2022). Nonetheless, the study by Anggara et al. (2021) reported that technology use in education, i.e., AR technology, is effective in influencing students' understanding and learning. Technology use also helps in improving student achievement in learning regardless of its use at home or school (Yunos et al., 2014).

Malaysia's Ministry of Education (MOE) has included AR within the national education system and has introduced this idea into textbooks taught in schools throughout the nation. Such adoption of AR paves the way for the use of the newest technological capabilities by students and teachers to involve teaching and learning within classrooms. Although, the extent to which the features presented in such textbooks in schools are utilized by the teachers and students is difficult to ascertain (Ziden et al., 2022). However, use of AR technology within the education system in Malaysia still remains in its infancy. At secondary school level, the use of AR in learning and teaching is rare in Malaysian education. While AR has been included in specific textbooks used in schools, whether or not the feature has been implemented is unknown and has received very little attention (Ziden et al., 2022). Besides, teachers are likewise sluggish to adopt mobile AR in the classroom (Nikou et al., 2021), even though both teachers and pre-service teachers are able to serve a critical role as change facilitators in accelerating the use and adoption of new technologies in learning process. The effective implementation of this technology largely relies on teachers' readiness and competence in its use (Barteit et al., 2021). Equally crucial is the readiness and acceptance of both teachers and pre-service teachers toward the adoption and integration of AR. Yet, their perceptions have not been professionally studied (Perifanou et al., 2023; Heintz et al., 2021). Moreover, research on teachers' acceptance of and inclination to use and apply AR in science instruction is limited (Alalwan et al., 2020; Arici et al., 2021; Faqih & Jaradat, 2021). Given this context, the current study is investigating the application of AR and would also like to discover to what extent it is adopted and willing to utilize AR for science instruction. Therefore, this study wants to achieve the following research inquiries:

1. What is the teachers’ level of acceptance in using Augmented Reality in teaching science?
2. What is the teachers’ level of readiness to use Augmented Reality in teaching science?
3. What are the teachers’ challenges to use Augmented Reality in teaching science?
4. Is there any significance difference between teachers’ readiness and teaching experience?
5. Is there any significant relationship between teachers' readiness and acceptance in using AR for teaching science?

LITERATURE REVIEW

Theory related in implementation of AR

Technology Acceptance Model (TAM)

Studies of technology acceptance have consistently demonstrated that user acceptance, in this case meaning the intention of the people to use and adopt a technology for its use (Dillon, 2001), is key to the successful implementation of information technologies. The most widely applied technology explanation model for users' intention to adopt technology is perhaps the Technology Acceptance Model (TAM) (Davis, 1989). TAM identifies two intention determinants: perceived usefulness, or the degree to which an individual believes that a system will assist in enhancing job performance, and perceived ease of use, or the degree to which a system is perceived as easy to use (Davis, 1989). The model is found to predict teachers' and pre-service teachers' intention to use technology in teaching contexts (Farjon et al., 2019; Scherer & Teo, 2019; Watson & Rockinson-Szapkiw, 2021).

Though comparatively few studies have applied technology acceptance models in investigating particularly AR adoption by educators, some recent research provides useful findings. For example, Rahmat and Mohamad (2021) determined perceived usefulness as the most valid predictor of pre-service teachers' intention to employ mobile AR. Now that TAM has been introduced, subsequent external determinants have been incorporated for improved explanatory ability, especially through the Unified Theory of Acceptance and Use of Technology (UTAUT) model (Venkatesh et al., 2003). UTAUT extends TAM through the inclusion of social influence, effort expectancy, performance expectancy, and facilitating conditions, factors that have been evidenced in various research studies to play a critical role in pre-service teachers' behavioral intention to use AR (Ateş & Garzón, 2023; Mikropoulos et al., 2022; Ning et al., 2019).

Teacher Acceptance to use AR in Teaching

Teachers' attitude and acceptance of AR are principal constructs since they determine the adoption of AR applications in educational practice. Tiede et al. (2022) reported that teachers reported a high degree of motivation and highly positive attitudes towards AR, and correlation analysis confirmed a significant relationship between attitudes and acceptance. As such, there is a need to closely monitor and evaluate these dimensions in order to ensure effective implementation of new technologies in education.

Teacher acceptance of AR is a condition precedent for the effective and successful implementation of technology in the teaching-learning process (Wei et al., 2015). Thematic analysis of six teachers' semi-structured interviews in Banerjee & Walunj (2019) identified 100% teacher acceptance of AR as a teaching resource. Perceived ease of use (PEOU) and perceived usefulness (PU) about AR as a teaching resource were positive in the study.

AR has showed promising potential to enhance learning experiences in various subjects and levels of education. Highly positive levels of self-efficacy, social influence, low levels of anxiety, and positive attitudes towards implementing AR were reported from a survey of science teachers in Semarang, Indonesia (Widiyatmoko et al., 2023). The findings indicate that science teachers are confident and ready to apply AR in their teaching.

Furthermore, when educators perceive AR as a learning aid and an enhancement of teaching approaches, their receptivity and motivation to implement AR will be likely to increase.

Mohamed Jamrus & Razali (2021) also surveyed secondary school teachers in Malaysia regarding the use of AR in teaching English reading and reported high levels of acceptance and readiness, while performance expectancy, effort expectancy, and social influence were observed to be key determinants. Similarly, Muryanti et al. (2023) examined kindergarten teachers' perceptions of AR storybook books and highlighted the level of acceptance and readiness determinants influencing the use of AR in early childhood education.

Yapıcı & Karakoyun (2021) carried out a case study of potential biology instructors and identified their positive attitudes towards integration with AR in biology instruction. In another study by Ibili et al., (2019), demonstrated that students and instructors have more positive attitudes toward applying AR to learning. Experiments have found that AR can decrease cognitive load and increase satisfaction and perceived usefulness, which are essential for its adoption and continued use.

Teacher Readiness to Use AR Technology in Teaching

Teacher readiness in the use of AR has become more and more an important factor in education (Kearney & Garfield, 2019). During the era of continually evolving information and communications technology, the integration of AR into instruction is highly potential to raise the quality of instruction and students' learning experience. As suggested in various studies, the significance of teacher readiness in relation to the adoption of AR technology in teaching processes was clearly corroborated. However, in order to effectively apply such a technology in teaching processes, a teacher needs appropriate expertise in relation to principles of AR and needs appropriate expertise in relation to the creation of such content in such teaching processes. As was clearly implied in the research findings of Kusmawan in 2016, a teacher's perception of having appropriate expertise in relation to technology, as well as appropriate innovation attitudes and administrative support, was likely to enable such a person to apply AR in teaching processes.

Research on Malaysian secondary school English teachers evaluated their acceptance, preparedness, and intention to implement AR in English reading classes. It was found that there was a high level of preparedness across the board with high positive correlations between preparedness (measured through perceived usefulness, ease of use, and attitude) and use intention for AR. The inference was that ready-to-adopt AR teachers also intend to use it in the classroom (Mohamed Jamrus and Razali, 2021).

Systematic review of Üral et al., (2025) discussed research on teachers' readiness to use AR technology in instruction, focusing on pre-service teachers. Differences in readiness based on training, technical expertise, and pedagogical self-efficacy were highlighted. The review integrated evidence from 42 relevant studies in multiple databases and provided information on the level of readiness of teacher candidates to adopt AR.

Maulyda et al., (2025) considered how the digital competence of teachers affects their AR media competence and readiness in elementary schools, with a focus on the necessity of digital literacy for AR readiness. Prepared teachers to utilize AR can create more engaging and relevant learning experiences for students, leading to better performance in academics. However, teachers' preparedness to prepare and implement AR material is necessary to provide these results. In addition, teachers' digital literacy includes the ability to facilitate students in acquiring required digital literacy skills to utilize AR, such as assessing digital information's authenticity and ethics in using technology.

Teachers are mostly positive about applying AR in their teaching activities. Research conducted by Marques & Pombo (2019) found that workshops and training undertaken under the EduPARK project have established that teachers feel prepared to incorporate mobile AR games into the schooling practice upon receiving proper training. This preparedness has also been evidenced in pre-service teachers who have revealed a readiness to apply mobile AR in their prospective teaching

Overall teacher willingness to implement AR media is pivotal in shaping students' learning experience. Reintegrated AR teachers can create a more interactive and experiential learning experience, increasing

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motivation and achievement. However, challenges in defining teacher readiness, for instance, lack of training, must be addressed as a matter of urgency. With consistent interventions in support and training, AR can flourish in education and provide more payoffs for students and educators (Mikropoulos et al., 2022; Nikou, 2024).

Challenges of using AR in Teaching

Despite the enormous potential for learning using AR, the literature also shows that there are challenges in constructing teachers' readiness to adopt this technology. Possibly the largest challenge is with the training. According to Muryanti et al., (2023) and Saforrudin et al., (2011), most teachers find that they are not ready to use AR because they do not have related training. Furthermore, infrastructural issues, i.e., the availability of necessary devices and internet infrastructure, can even become a deterrent. Therefore, further effort should be invested to ensure quality training and suitable infrastructure in place to support the introduction of AR in educational environment.

Fearn & Hook (2023) concluded that teachers indicate low self-efficacy with AR technology, poor training, insufficient time to prepare and implement AR, and opposition to altering conventional teaching practices as major obstacles. Teachers are most concerned with how AR will actually work in class and need more professional development and information about the potential and use of AR in classrooms. Time constraints and technical issues with implementing AR add to the challenge. Teachers are more likely to implement currently existing digital tools that are simpler to use and more curriculum-aligned than implement AR unless they have more support and training. In addition, technologies like solid IT and device access are of central importance to fruitful AR use in scientific learning.

A study by AlNajdi (2022) determines some AR limitations like over-reliance on virtual information, difficulty in maintaining superimposed content, accessibility issues for differently abled learners, and poor integration with instructional design. Teachers' incapacity to design instruction and to modify AR content are important obstacles to effective use. The study stresses that AR systems should be created based on instructional models that include learner requirements and curriculum requirements.

A systematic narrative review of 53 educational studies of AR and VR by Zekeik et al., (2025) found advantages including enhanced engagement and learning, but also commonly reported barriers of technological limitations, cost, teacher training shortages, lack of pedagogical frameworks, and equity concerns regarding device access. The review called for more research focused on overcoming obstacles to the adoption of AR into instructional practice.

Samad et al., (2021) outlined benefits and limitations of AR in education, emphasizing the gap between the virtual and real world. Amongst cited limitations are technical problems, educator preparedness, and insufficient contextual adaptation of AR content, which generally affect mass adoption of AR. The majority of teachers lack AR experience (Heintz et al., 2021). Specifically, they do not have proper pedagogical and technical skills such as programming skills and managing 3D design programs and also practical experience in AR content creation and integration into teaching (Heintz et al., 2021; Pombo, 2021; Tzima et al., 2019; Marques & Pombo, 2019; Alalwan et al., 2020; Alzahrani, 2020).

Prior Studies on Science Teachers' Integration of AR

Previous study by Wang et al., 2023; Weng et al., 2020 and Yapıcı & Karakoyun, 2021, AR is usually described as rather new and useful technology in biology (including ecology) teaching and learning at all levels. According to Nurhasanah and Widodo (2019), the use of AR in biology classes will definitely bring more curiosity in school among students. Similarly, Hung et al., (2017) added that AR is not specifically superior to other supports and learning materials but is just as good and can aid learners in biology learning, capture their attention, and reduce class boredom.

A study by Yahya & Omar (2019) undertook a study on how teachers perceive the use of AR programs in teaching simple electronic circuits. The study conducted a survey among teachers who replied to their views and perceptions of using AR in the context of teaching simple electronic circuits. The results show that the teachers are positive about the use of AR applications in teaching elementary electronic circuits and see the promise of AR in increasing the effectiveness of teaching and learning and boosting students' involvement and interaction, rendering it more stimulating and fun.

AR technology has also been introduced into the teaching of physics. Ropawandi et al., (2022) reported that the effect of AR technology on understanding concepts in electricity in an online learning environment for 11th-grade learners was investigated. The results revealed that AR technology improved electrical concept understanding among the experimental group students compared to the control group with a significant difference between the two groups. Studies on the use of worksheets with the incorporation of AR videos prove its support in promoting achievement in Physics high school students (Bakri et al., 2020). Similarly, study in Physics Simulator using AR with the use of Kinect V2 technology proves that the students agreed on the use of AR to support the learning in enhanced environments (Sung et al., 2019).

Another study indicated that mobile AR is an effective pedagogical practice in science teaching. It has been found to support students in learning through helping them understand abstract and complex concepts, such as physics lessons in forces and motions (Fidan & Tuncel, 2019), enhancing students' self-efficacy and conceptual knowledge in physics teaching (Cai et al., 2021), and increasing motivation, achievement, and mental processing in natural science inquiry activities (Pedaste et al., 2020).

RESEARCH METHODOLOGY

This study employed descriptive correlational design of quantitative research in the study of correlation between acceptance and their receptiveness to use AR as a teaching tool. Descriptive correlational design was employed since it enables one to study the relationship between variables without manipulating them and is highly suitable in the study of attitude and behavior in schools (Creswell & Creswell, 2018). This is a prevalent design in educational research since it provides information on relations and trends that can guide intervention targeted (Fraenkel, Wallen, & Hyun, 2019).

Data were collected using a Likert-scale, structured questionnaire, a conventional instrument for measuring attitudes and perceptions in educational research (Likert, 1932; Boone & Boone, 2012). The questionnaire comprised three sections:

- Part A: Demographic Data that collected background information such as age, gender, years of teaching experience and experience in using AR.
- Part B: Teachers' acceptance of AR adapted from Unified Theory of Acceptance and Use of Technology (UTAUT) by Venkatesh et al. (2003). This section included Performance Expectancy (PE), Effort Expectancy (EE) and Social Influence (SI) as it is going to measure the level of acceptability on a five-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree).
- Part C: Teachers' Readiness to use AR in teaching science adapted from Schmid et al., (2020) using TPACK framework. In this part, teachers' readiness was assessed using a five-point Likert scale.
- Part D: Teachers' challenges in implementing AR technology. In this part, the main challenges were identified using a five-point Likert scale.

The sample for this research was from the STEM teachers at a daily secondary school in Selangor. A purposive random sampling was employed with purpose because it allows researchers to collect data from the target group that is conveniently to conduct. A total of 100 in-service science teachers who took part in the study constitute a sample size that fits proposed sample sizes for correlational studies and is adequate for measuring significant relationships between variables.

Data were collected via an online survey. It took two weeks to leave the survey open so that ample time would be available for the teachers to participate. The study's focus was well defined so that the quantum of teachers' acceptance and preparedness in applying AR as a tool of science education could be measured. Voluntary participation was ensured with the guarantee of confidentiality of response. Data gathered were analyzed using descriptive and inferential statistics. Descriptive statistics (frequency, percentage, mean, and standard deviation)

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were used to present demographic information as well as the teachers' acceptance of AR and their readiness. Inferential statistics, specifically correlation analysis, were used to examine the relationship between teachers' acceptance of AR and their readiness. One- Way ANOVA were also used to evaluate the difference between teachers' readiness and years of teaching experience. The pilot study was carried out to determine the reliability and validity of the research instruments. The results indicated that all constructed items demonstrated a high level of reliability, as shown in the Table 1.

Table 1 Cronbach's alpha reliability

Section	Item(s)	Cronbach's Alpha
Acceptance	10	0.870
Readiness	8	0.943
Challenges	8	0.910

RESULTS AND DISCUSSION

Table 2 summarizes the demographic profile of the respondents (N=100). In terms of age, the largest group was 31–45 years, accounting for 42% (n=42), followed by 46–50 years at 32% (n=32). Meanwhile, 19% (n=19) were aged 25–30 years and 7% (n=7) were 51–55 years. The sample was predominantly male, comprising 71% (n=71), while females represented 29% (n=29). With respect to AR usage, 69% (n=69) had never used AR, whereas 31% (n=31) had prior experience. In terms of working experience, most respondents, 61% (n=61), reported more than 15 years of service, followed by 30% (n=30) with 4–14 years and 9% (n=9) with less than 3 years.

Table 2 Demographic Profile of the Respondents

Item	Frequency (N=100)	Percentage (%)
Age		
25-30	19	19
31-45	42	42
46-50	32	32
51-55	7	7
Gender		
Male	71	71
Female	29	29
Have you ever used AR?		
Yes	31	31
No	69	69
Teaching Experience		
Less than 3 years	9	9
4-14 years	30	30
More than 15 years	61	61

Level of Teachers' Acceptance in using AR in Teaching Science

Table 3 illustrates teachers' acceptance of using AR in teaching science. Overall, the responses reveal generally low to moderate agreement across the items. The highest mean score was recorded for the statement "AR technology with all its features increases work performance" (M=2.72, SD=1.120), followed closely by "I can easily teach someone to use AR technology" (M=2.69, SD=1.022). Other items, such as "AR technology increases productivity" (M=2.45, SD=1.366), "School senior management assist in using AR technology" (M=2.44, SD=1.234), and "AR technology user interface is clear and understandable" (M=2.39, SD=1.053), also showed relatively higher mean scores. Meanwhile, items such as “It is easy to learn how to use AR technology” (M=2.33, SD=1.231), “AR technology makes things faster” (M=2.32, SD=1.053), and “In general, the school supports the AR technology” (M=2.31, SD=1.361) were rated slightly lower. The lowest agreement was observed for the statements “Significant people think I should use AR technology” (M=2.25, SD=1.201) and “AR technology is beneficial for my work” (M=2.18, SD=1.242). Collectively, these findings suggest that teachers’ acceptance of AR in science teaching remains limited, with perceptions leaning towards neutral rather than strong endorsement.

Table 3 Teachers’ Acceptance in using AR in Teaching Science

No	Mean (M)	Std. Deviation (SD
AR technology is beneficial for my work.	2.18	1.242
AR technology makes things faster.	2.32	1.053
AR technology increases productivity.	2.45	1.366
AR technology with all its features increases work performance.	2.72	1.120
AR technology user interface is clear and understandable.	2.39	1.053
I can easily teach someone to use AR technology.	2.69	1.022
It is easy to learn how to use AR technology.	2.33	1.231
Significant people think I should use AR technology.	2.25	1.201
School senior management assist in using AR technology.	2.44	1.234
In general, the school supports the AR technology.	2.31	1.361

The findings in this study were aligned with existing studies conducted by Mohamed Jamrus and Razali (2021) which found that secondary school teachers showed their acceptance of AR technology reinforced based on both perceived ease of use and performance expectancy. This also aligned with the TAM theory which established perceived ease of use alongside perceived usefulness as fundamental factors to drive technology adoption (Davis, 1989). TAM has been tested rigorously as a reliable measure to predict how teachers and pre-service teachers intend to integrate technology in learning contexts. (Farjon et al., 2019; Scherer & Teo, 2019; Watson & Rockinson-Szapkiw, 2021). There was another study among science teachers in Semarang, Indonesia, that indicated high levels of self-efficacy and social influence scores, low anxiety, and positive attitudes toward AR (Widiyatmoko et al., 2023). This suggests that science teachers are confident and willing to integrate AR into their teaching practices. When educators see AR as supportive for students learning and enhancing their teaching strategies their likelihood of accepting and seeking to implement AR increases.

Level of Teachers’ Readiness in using AR in Teaching Science

Table 4 presents the findings on teachers’ readiness to integrate AR in science teaching. Overall, the results indicate a generally low level of readiness. The highest mean score was observed for the statement “I can select AR technologies to use in my classroom to enhance what I teach, how I teach and what students learn” (M=2.51, SD=1.243). This was followed by “I can choose AR technologies that enhance the teaching approaches for a lesson” (M=2.40, SD=1.189) and “I can choose AR technologies that are suitable for the teaching approaches and teach students how to use it” (M=2.38, SD=1.420). Slightly lower mean scores were recorded for “I can choose AR technologies that enhance the content for a lesson” (M=2.31, SD=1.376) and “I can use strategies that combine content, AR technology and teaching approaches that I learned about in my coursework” (M=2.25, SD=1.344). The lowest mean scores were obtained for “I can provide leadership in helping others to coordinate the use of content, AR technologies and teaching approaches at my school and/or my districts” (M=2.21, SD=1.175) and “I can teach lessons that appropriately combine my teaching subject, technologies and teaching approaches” (M=2.19, SD=1.269). Therefore, these findings suggest that teachers’ readiness to use AR in science teaching is limited, with relatively higher confidence in selecting AR tools for classroom purposes but lower confidence in leadership and the integration of AR with subject content and pedagogy.

Table 4 Teachers' Readiness in using AR in Teaching Science

Items	Mean (M)	Std. Deviation (SD)
I can use strategies that combine content, AR technology and teaching approaches that I learned about in my coursework.	2.25	1.344
I can choose AR technologies that enhance the content for a lesson.	2.31	1.376
I can select AR technologies to use in my classroom to enhance what I teach, how I teach and what students learn.	2.51	1.243
I can teach lessons that appropriately combine my teaching subject, technologies and teaching approaches.	2.19	1.269
I can provide leadership in helping others to coordinate the use of content, AR technologies and teaching approaches at my school and/or my districts.	2.21	1.175
I can choose AR technologies that enhance the teaching approaches for a lesson.	2.40	1.189
I can choose AR technologies that are suitable for the teaching approaches and teach students how to use it.	2.38	1.420

Readiness level in this study may be low due to technological ability and lack of professional development training. Teachers are mostly not ready since they do not possess technical skills and professional development training on how to integrate AR into the instructional practices. This is evidenced by findings that highlight the need for technological ability and professional development to facilitate efficient adoption of AR in learning. For instance, studies have suggested that teachers' readiness and competence to apply AR are heavily based on their level of technological competence and availability to particular training programs (Salehi, 2025; Duc et al., 2025). Further, in one study, Tzima et al., (2019) found that teachers in Greece were not well equipped to handle AR because they had no exposure to training and experience with computers. These findings are consistent with this research, wherein it was discovered that teachers are poorly equipped with skills and knowledge necessary to implement AR effectively. Further, Ayaz & Yanartas (2020) also indicated that effort expectancy, for instance, the ease of learning and implementing AR, has a vital impact on teachers' preparedness. If teachers believe AR is complex or time-consuming, their planning to use it is less. Similarly, Schmid et al., (2020) emphasized the need for targeted professional training in order to enhance teachers' readiness to embrace AR. They opined that if teachers are not well-trained, they might lack self-confidence in using AR tools in creating engaging and effective learning activities. Hanefarezan et al. (2022) also carried out another study on Malaysian teachers' readiness to use AR to teach Arabic and found comparable results. Therefore, enhancing the digital literacy of educators and providing comprehensive training on AR technologies are critical measures towards raising their readiness and confidence in applying the technologies to instruction (Moreno-Guerrero et al., 2021).

Teachers' Challenges in using AR in Teaching Science

Table 5 indicates the challenges faced by teachers in the use of AR for teaching science. The greatest challenge reported was training or professional development, with the highest mean score of 3.95 (SD=1.201). This was closely followed by difficulty in assessing and evaluating AR learning activities (M=3.90, SD=1.275) and less time for lesson planning and implementation (M=3.82, SD=1.336). Limited availability of AR technology or software (M=3.79, SD=1.166), insufficient finances or funds for rollout (M=3.75, SD=1.344), and challenges in the alignment of AR activities to curriculum objectives (M=3.74, SD=1.169) were also found to be significant barriers. Meanwhile, student readiness to leverage AR effectively (M=3.67, SD=1.272) and resistance to change or hesitance to adopt new technologies (M=3.57, SD=1.289) were relatively lower but are still significant. So, the findings here suggest that difficulties teachers experience in using AR are mainly structural and systemic, i.e., inadequate training, facilities, and incorporation within the curriculum, while student-centered and attitudinal issues are secondary but significant.

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Table 5 Teachers' Challenges in using AR in Teaching Science

Items	Mean (M)	Std. Deviation (SD)
Lack of Access to AR Devices or Software.	3.79	1.166
Lack of Training or Professional Development.	3.95	1.201
Time Constraints for Lesson Planning and Implementation.	3.82	1.336
Assessment and Evaluation of AR Learning Activities are difficult.	3.90	1.275
Concerns about students' readiness or ability to use AR effectively.	3.67	1.272
Resistance to change or reluctance to adopt new technologies.	3.57	1.289
Difficulty in aligning AR activities with curriculum objectives.	3.74	1.169
Limited resources or funding for AR implementation.	3.75	1.344

The findings of this study align with those of Perifanou et al. (2023), who identified inadequate professional development programs as the foremost challenge to AR adoption. In their study, hands-on training workshops and regular training support emerged as key factors to enhance teachers' mastery and self-perceived efficacy in employing AR systems. Similarly, Muryanti et al. (2023) and Saforrudin et al. (2011) reported that many teachers feel underprepared to use AR due to limited access to relevant training opportunities. Additionally, Fearn & Hook (2023) found that teachers report low self-confidence with AR technology, inadequate training, limited time to prepare and use AR, and resistance to changing traditional teaching methods as significant barriers. Teachers often feel uneasy about how AR will work in practice and need more professional development for successful AR adoption in science teaching.

Differences in Teachers' Readiness Based on Teaching Experience

Table 6(a) presents the mean scores of teaching experience among science teachers. The results indicate that teachers with more than 15 years of experience recorded the lowest mean score (M=1.92), while those with 4 to 14 years of experience obtained the highest mean score (M=3.02) among the three teaching experience groups.

A one-way ANOVA was conducted to examine whether teachers' readiness differed according to years of teaching experience. As shown in Table 6(b), the analysis revealed a statistically significant difference in teachers' readiness across the three teaching experience groups, $F(2, 97) = 18.161$, $p < .001$. Since the obtained p-value was less than the significance level of .05, the null hypothesis was rejected. These findings indicate that teachers' readiness differed significantly based on their years of teaching experience. However, the ANOVA does not identify which specific groups differed significantly. Therefore, a post hoc test was conducted to determine the pairs of groups that contributed to the significant differences.

Table 6(a) Descriptive data of teaching experience among Science Teachers

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Less than 3 years	9	2.74	.722	.241	2.18	3.29	1	3
4-14 years	30	3.02	.519	.095	2.83	3.21	2	4
More than 15 years	61	1.92	.975	.125	1.67	2.17	1	5
Total	100	2.33	.979	.098	2.13	2.52	1	5

Table 6 (b) One-way ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	25.847	2	12.923	18.161	.000
Within Groups	69.025	97	.712		
Total	94.872	99			

Table 6(c) presents the results of the post-hoc Bonferroni comparisons to determine where the significant differences occurred. The analysis revealed that only one mean score was significantly different from the others. Teachers with more than 15 years of teaching experience produced significantly different results compared to the other two groups. Specifically, teachers with more than 15 years of teaching experience had a significantly lower mean score (M=1.92) than those with less than 3 years of experience (M=2.74) and those with 4 to 14 years of experience (M=3.02). These findings suggest that teaching experience is a significant factor in readiness, with more experienced teachers showing significantly lower levels of readiness for AR use in science teaching. This addresses the challenge that many older or veteran teachers are resistant to participating in training or professional development activities that would update their technological skill sets (Aldridge & Witherspoon, 2023).

However, this study's result disagrees with those of Jwaifell (2019) who specifically studied the readiness of in-service science teachers and ascertained that teaching experience had no significant effect on their readiness to apply AR in teaching. The study discovered no distinction between teachers with more and less teaching experience years that both groups are as prepared to accept AR in teaching after adequate professional exposure and growth. This means regardless of the number of years that a teacher has been teaching, his or her readiness to use AR technology is equal. Similarly, Maulyda et al., (2025) demonstrated that demographic variable such as age and teaching experience was discovered to have an effect on the role of digital competence on AR skills, yet not directly on readiness. This suggests that while older teachers or those with more experience might have different levels of digital competence, their overall readiness to adopt AR is not significantly impacted.

Table 6 (c) LSD Multiple Comparisons

Bonferroni

(I)	(J) Scale Scale	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Less than 3 years	4-14 years	-.285	.321	1.000	-1.07	.50
	More than 15 years	.812*	.301	.025	.08	1.55
4-14 years	Less than 3 years	.285	.321	1.000	-.50	1.07
	More than 15 years	1.097*	.188	.000	.64	1.55
More than 15 years	Less than 3 years	-.812*	.301	.025	-1.55	-.08
	4-14 years	-1.097*	.188	.000	-1.55	-.64

*. The mean difference is significant at the 0.05 level.

Relationship Between Teachers' Readiness and Acceptance in using AR in Teaching Science

Table 7 presents the Pearson correlation analysis between acceptance and readiness in using AR among science teachers. The results indicate a very strong, positive, and significant relationship between readiness and acceptance ($r = 0.900$, $p < .001$). This means that the teachers with greater readiness to utilize AR are also more prone to have greater acceptance to implement AR in science education. The outcome is also in line with the research conducted by Mohamed Jamrus & Razali (2021) which revealed those teachers being ready and accepting AR are very likely to intend to use it to teach. Furthermore, another scholarly article on teachers' attitudes and self-efficacy towards AR in STEM education also determined that strong correlations existed between teachers' positive attitudes and adopting AR tools in their teaching (Ripsam & Nerdel, 2024).

Table 7 Correlation between teachers' readiness and acceptance in using AR in teaching science

		Acceptance	**Readiness**
Acceptance	Pearson Correlation	1	.900**
	Sig. (2-tailed)		.000
	N	100	100
Readiness	Pearson Correlation	.900**	1
	Sig. (2-tailed)	.000	
	N	100	100
**. Correlation is significant at the 0.01 level (2-tailed).			

CONCLUSION

Overall, this study confirmed that Malaysian STEM teachers had low to moderate readiness and acceptance in the use of AR in teaching science, and the two constructs were positively and strongly correlated. This means that more ready teachers are also more likely to accept and adopt AR into their instructional practice. While the advantages of AR were expected, many challenges were also noted, from the lack of training to time pressures, and the inability to align AR to curriculum requirements. These findings point out that successful AR integration is very much based on professional development, technical expertise, and administrative support. Readiness differences by years of experience in teaching further indicate that tailored training programs are needed, especially for more experienced teachers who were likely to be lower in readiness. Therefore, enhancing digital literacy, continuous professional development, and adequate infrastructure are essential steps to facilitate effective AR adoption. Ensuring them will enable educators to create more interactive and creative learning environments, ultimately enriching students' learning in science education.

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