Design and Development Research (DDR) Approach in STEM Project: Augmented Reality Module to Improve the Quality of Education for Rural Students in Malaysia

Wan Nurul Huda Wan Ab Kadir[1,*], Nur Izwani Mohd Shapri[1], Nurulasyikin Hassan[2], Mohd Zakhiri Yusof[3] & Fatimah Mohamed[1]

[1]Faculty of Science and Mathematics, Sultan Idris Education University, Malaysia

[2]Faculty of Human Sciences, Sultan Idris Education University, Malaysia

[3]Sultan Azlan Shah Polytechnic, 35950, Malaysia

*Correspondence: Faculty of Science and Mathematics, Sultan Idris Education University, 35900, Malaysia. Tel: 60-19-730-0235. E-mail: wannurulhuda@fsmt.upsi.edu.my

Received: August 14, 2025 Accepted: January 23, 2026 Online Published: February 7, 2026

doi:10.5430/jct.v15n1p242 URL: https://doi.org/10.5430/jct.v15n1p242

Abstract

This article describes the development of a STEM project, namely the Augmented Reality module, aimed at improving the quality of Science education for rural students in Malaysia. This study employs the Design and Development Research (DDR) method consisting of three phases: needs analysis, development and design, and evaluation. Each phase follows a systematic process, including the need analysis process, the Fuzzy Delphi Technique, expert validation, and evaluation through the effectiveness of the module on rural students in Malaysia. This study adopts a quantitative development approach. With a focus on applying STEM education through Augmented Reality (AR) to improve achievement in the subject of science, this study also seeks to improve the quality of education and reduce inequalities for rural students in Malaysia. The findings demonstrate that this AR module allows students to directly view interactive 3D models through mobile devices or tablets, allowing science concepts that are difficult to understand theoretically to be comprehended more easily through visual and contextual means. Technological learning through AR provides a fun and interactive learning experience compared to traditional methods for rural students in Malaysia. Rural students who may have limited exposure to advanced technology are likely to be more excited and motivated to learn through AR, thereby improving their achievement and understanding in Science. This project aligns with Sustainable Development Goal (SDG) 4: Quality Education and SDG 10: Reduced Inequalities for rural students.

Keywords: STEM project, module development, DDR approach, augmented reality, quality education, rural students, STEM education

1. Introduction

1.1 Challenges Faced by Rural Students

Students in rural areas often face significant challenges in learning Science due to infrastructure constraints, limited digital access, and a lack of trained educators. A recent scoping review found that rural schools often lack learning resources, specialised teachers, and access to digital technology, which collectively undermine Science, Technology, Engineering, and Mathematics (STEM) learning outcomes (Salame et al., 2025). Meanwhile, a major report on the STEM education landscape in the Malaysia region highlighted significant differences between urban and rural countries regarding accessibility of the Science curriculum, public-private partnerships, along with less consistent policy support, especially in rural areas (Abdul Hamid & Chowopass, 2024). It was discovered that rural students in Malaysia often show low self-esteem in Science, despite showing positive attitudes towards the subject, reflecting a gap between interest and confidence to succeed in this academic subject (Othman et al., 2022). Mustafa, Nguyen, and Gao (2024) conducted an international study examining the impact of digital divide policies on technology integration in rural schools, later explaining that unequal access to digital infrastructure perpetuates educational inequalities between urban and rural students. Therefore, the context of rural education requires innovative pedagogical and policy approaches to cater to this problem and improve achievement in Science learning, especially for rural students.

Based on a study by Hasmiza Yaakob et al. (2023), mastery of science subjects is very important among students in Malaysia. The particular research revealed the main problem faced by rural school students in science subjects, which was a negative attitude towards science subjects. Rural school students also tend to experience difficulties in understanding the topics being studied. This situation affects students' mastery and concentration in class, further influencing their motivation towards science subjects. Students' ability to focus on the learning process in the classroom is an important aspect in ensuring their mastery of the topics studied. This ability helps improve the skills needed in school, such as reading, writing, and counting. Phang et al. (2012) stated that the factors leading to the decline in student achievement in the science subjects include a lack of concentration in class, unplanned time management, and a lack of exposure related to question answering techniques. Students in rural areas tend to be less competitive and less motivated to study due to work commitments, long distances from their schools, and a lack of facilities at home for studying. They are also less likely to be exposed to the concepts and benefits of pursuing the science stream and suffer from a comparative lack of practical facilities.

In addition, schools in rural areas in Malaysia face problems related to internet access. Nowadays, learning depends more on the use of tablets and laptop computers with extensive internet connectivity to facilitate the process of adding knowledge for students. However, this is not often the case in rural schools. Rural students additionally perceive science as a difficult subject that is not relevant to their daily lives. The lack of innovative and practical science teaching causes rural students to lack motivation to study this subject. This situation is further influenced by their environmental and socio-economic factors, which reduce their interest in science subjects (Mohd Yusof et al., 2024). Besides, financial implications are disadvantageous for rural students. Limited funding for educational institutions restricts the implementation of active, creative, and innovative learning approaches (Le et al., 2021).

Therefore, based on the constraints faced by rural students in learning science, this study took the initiative to develop science learning with AR innovation for rural students in Malaysia. Learning science with the Augmented Reality application will simultaneously provide an effective science learning environment without the need for internet access to rural students. The effectiveness of this learning method can be observed through the achievement of rural students in the science subject after undergoing the intervention.

1.2 STEM Education: Augmented Reality

Learning based on Augmented Reality (AR) offers several benefits in overcoming the challenges faced in science education. For instance, AR enables students to understand complex and abstract scientific concepts, including science processes, more clearly through three-dimensional (3D) visualisation. It also provides an effective interactive alternative to visual understanding (Chong et al., 2021). Furthermore, it offers a more immersive learning experience even without physical science equipment. In rural environments where resources and facilities are often limited, AR technology can be employed to simulate demonstrations that would normally require expensive laboratories and equipment. On top of that, students can interact with this simulation through mobile devices like tablets or smartphones (Rahim & Yusof, 2022).

AR-based learning can make science learning more engaging and enjoyable. Students often feel more involved in learning when science concepts are visualised and brought to life through AR technology. It further increases their motivation to learn, especially for students in rural areas, who may perceive science as a difficult subject (Abdullah et al., 2023). For schools in rural areas that may lack traditional educational resources such as quality textbooks or learning support materials, AR offers access to digital learning materials that can be used repeatedly at no additional cost. Students can use AR applications on their devices to access interactive learning resources without internet connectivity (Nordin & Hamid, 2024). Through AR, rural students are also exposed to advanced technologies that are increasingly important in the digital world. This not only increases their interest in science but also helps them build important technological skills to face the challenges of the Industrial Revolution 4.0, such as data manipulation skills and mastery of digital tools (Zainal et al., 2023). Furthermore, AR can help reduce the educational gap between urban and rural schools by offering comparable learning experiences, thereby improving the quality of education and reducing inequalities for rural students in Malaysia. All in all, AR has the potential to balance the quality of education throughout Malaysia without relying entirely on physical infrastructure (Chong & Rahman, 2023).

The use of AR in science learning is increasingly recognised as having the potential to improve student achievement. Many studies have shown that the integration of AR technology can provide a more interactive and interesting learning experience for students, making it easier for them to understand abstract science concepts, such as molecular structures, biological systems, and universe phenomena (Halim et al., 2022). According to Azhar and Mustapha (2021), the use of AR in science teaching increases students' academic achievement, as it provides clearer 3D visualisation and is able to stimulate students' memory of the topics studied. In addition, a study from Shamsudin et al. (2023) stated that the use of AR in science classes can improve students' understanding of concepts and, at the same time, can improve their academic achievement. Therefore, this study focuses on examining the effectiveness of technological learning using AR for rural students in Malaysia to overcome the constraints faced by rural students in science subjects.

2. Literature Review

2.1 Augmented Reality in Science Education

Augmented Reality (AR) technology is increasingly recognised as an innovative learning tool that can interactively visualise abstract science concepts by combining real-world and virtual elements in real time (Chang et al., 2022). A recent meta-analysis using data from 37 studies in K-12 science education showed that the use of AR has a moderate to strong effect on student learning achievement, indicating significant potential for improving academic outcomes. In addition, AR has the potential to increase student engagement and understanding by bringing abstract concepts to life (Na & Yun, 2024). For instance, a study conducted by Ziden et al. (2022b) on the AR-NutricARd application among secondary school students discovered a significant increase in achievement and motivation in science learning compared to traditional methods. Meanwhile, a systematic review by Vidak et al. (2023) also showed that AR can facilitate physics learning by reducing cognitive load, accelerating conceptual understanding, and increasing collaboration between students. Therefore, integrating AR in science teaching for rural students in Malaysia can be viewed as an approach with high potential to strengthen student understanding and overall achievement.

2.2 Experiential Learning Theory and Augmented Reality-Based Learning

Experiential Learning Theory (ELT) is among the major learning theories, emphasising that learning occurs most effectively when acquired through direct experience. This theory was introduced by Kolb (1984), who defines learning as a process in which knowledge is created through the transformation of experience. According to Kolb, learning is not the result of passive transfer of information, but rather occurs through the active involvement of individuals in meaningful learning experiences.

Kolb (1984) proposed a model of the experiential learning cycle consisting of four main stages: concrete experience, reflective observation, abstract conceptualisation, and active experimentation. The concrete experience stage refers to an actual experience encountered by the student. The student will then go through the process of reflective observation, which involves reflecting on the experience. Through this reflection, the student builds conceptual understanding in the abstract conceptualisation stage, before applying the concept or idea in a new situation through active experimentation. This cycle shows that learning is dynamic and continuous, thus requiring active student involvement at each stage.

In the context of technological education, especially the use of AR, ELT provides a very strong theoretical foundation. AR refers to a technology that incorporates digital elements such as three-dimensional objects, animations, and virtual information into real-world environments in real time. The main feature of AR, being interactive and immersive, makes it in line with the basic principles of ELT, which emphasise learning through direct experience. The use of AR in learning allows students to have authentic, concrete experiences through direct interaction with virtual objects integrated into the real world. For example, in science learning, students can manipulate three-dimensional molecular models, conduct experimental simulations, or explore biological processes that are difficult to observe physically. These experiences not only enhance conceptual understanding but also make learning more meaningful and contextual (Mansour et al., 2025).

The visualisations provided by AR help students reevaluate their experiences and identify connections between actions and learning outcomes. Next, students form conceptual understanding through abstract conceptualisation, where the visual and interactive experiences of AR facilitate the construction of complex abstract concepts, such as scientific phenomena or microscopic processes that are difficult to understand through traditional methods (Ibáñez & Delgado-Kloos, 2018). Empirical studies also support the suitability of ELT in AR-based learning. In a study by Chen et al. (2025), an AR learning approach was used based on experiential learning in science education. The study results then presented significant improvements in students who engaged in learning using ELT-based AR in terms of academic achievement, learning engagement, and conceptual understanding compared to conventional teaching methods.

Overall, ELT provides a relevant and effective conceptual framework to support AR-based learning. The combination of direct experience, reflection, concept building, and knowledge application makes AR a learning approach that is in line with the needs of 21st century education. Therefore, the use of AR designed based on ELT principles has great potential to improve the quality of learning, especially in the fields of science and technology-based education.

2.3 Design and Development Research (DDR)

This study utilises the Design and Development Research (DDR) approach, which consists of three phases and is well-suited for module development and testing its effectiveness. Richey and Klein (2007) stated that the DDR approach is a systematic study of the design, development, and evaluation processes to establish an empirical basis for creating instructional products, including a module. It enables researchers to plan, design, develop, and test a product systematically while generating scientific evidence to improve understanding of the design and development process (Mohd Ridhuan Jamil & Nurul Rabihah Mat Noh, 2020; Hanis et al., 2025b). According to Richey and Klien (2007), DDR has many advantages over design and development studies by allowing practical evaluation of a product’s effectiveness. Therefore, this study applies the DDR design approach as it can meet the needs of researchers to develop an AR module for science subjects for rural students in Malaysia and test its effectiveness on their academic achievement.

2.4 Isman Teaching Model

The Isman Teaching model (Isman, 2011) was applied as a guide during the teaching and learning process. This model introduces a new teaching design based on active learning. During teaching and learning activities, students are actively engaged and use cognitive learning to build new knowledge based on their existing experiences to solve a problem (Isman, 2011). The Isman model also emphasises that to produce new knowledge, the help of technological tools in education is also used to facilitate the teaching and learning process. There are five steps (phases) involved in the active teaching and learning process based on Isman Teaching model: input, process, output, feedback, and learning. The Isman model, which emphasises learning with the help of technology, is very consistent with the learning modules based on AR applications found in this study.

3. Research Methodology

The methodology for this study was based on the Design Research and Development (DDR) approach, which provides a systematic framework for creating and testing an educational module (Richey & Klein, 2007). The DDR approach, as described by Richey and Klein (2014) and others (Mohd Ridhuan Mohd Jamil & Nurul Rabihah Mat Noh, 2020; Saedah Siraj et al., 2020), is well-suited for the interactive development of products and teaching tools. This study uses the DDR framework to develop the AR Module as a teaching product. The DDR process is divided into three main phases: Needs Analysis, Design and Development, and Evaluation.

The expert sample to obtain agreement on the elements and content of this module consisted of 25 people. These experts were experienced Science teachers with more than five years of teaching experience. Meanwhile, the sample for students comprised 74 rural students in Malaysia who took science subjects and were 15 years old. There were two questionnaires for this study, namely the Expert Agreement Questionnaire to determine the elements in the development of the AR Module. The second questionnaire was the AR Module Effectiveness Questionnaire (pre-post test) given to rural Science students to see the effectiveness of the AR Module for rural students.

3.1 Phase 1 DDR: Need Analysis

The needs analysis phase is a phase that must be carried out for a development study. It is the first phase in the DDR study (Richey & Klein, 2014). This phase aims to identify the needs for the module to be developed. It is a very important phase as researchers can obtain information from the target group on the needs of the module to be designed and developed (Mohd Ridhuan Jamil& Nurul Rabihah Mat Noh, 2020). McKillip (1987) stated that needs analysis involves identifying and assessing needs to decide how to evaluate a problem and develop a specific solution for a target population. This process is very important in determining the extent to which a study is carried out to solve a problem (Usher & McKillip, 1988). The needs analysis questionnaire was built based on the Discrepancy Model, which has been widely used by researchers in conducting needs analysis, especially in the field of education (McKillip, 1987). As stated by McKillip (1987), there are five steps in carrying out the needs analysis process, namely: identifying users and uses of needs analysis, describing the target population, identifying needs, assessing the importance of needs, and discussing the results of the needs analysis. The needs analysis in this study was conducted through a questionnaire administered to science teachers in rural schools around Malaysia. Questionnaires were chosen as they enable researchers to gather information that can lead to more efficient solutions to problems (Mohd Ridhuan Jamil & Nurul Rabihah Mat Noh, 2020). The needs analysis of this AR Module was descriptively analysed based on the questionnaire items, while the interpretation of the mean score was determined based on the cut-off point method.

3.2 Phase 2 DDR: Design and Development; (Fuzzy Delphi Method)

According to Den et al. (2006), the module design and development phase can be of importance in the field of education because: (i) a module to be developed is closely related to the field of education, (ii) the module development process must have scientific values and can be supported by certain theories, and (iii) the module to be developed can strengthen teaching and learning in the field of education. Thus, the Fuzzy Delphi method was selected to identify the expert consensus on the components and elements for the design and development of the AR Module, including the aspects of objectives, content, elements, and delivery media. The selected experts consisted of those from the Education and Science curriculum involved in the design and development process of the AR Module. Items 1-5 represent the elements that received expert agreement to be included in this AR Module. Table 1 presents these items, which correspond to the components found in the AR Module.

Table 1. Elements for AR Module Development

Item 1	AR Module Elements
1	STEM-based learning is suitable as an element for the development of the AR Module.
2	Module learning is suitable as an element for AR Module development.
3	Learning the theory of Science is suitable as an element for the development of the AR Module.
4	Practical science learning is suitable as an element for the development of the AR Module.
5	STEM Project-based Learning is suitable as an element for the development of the AR Module.

For obtaining expert consensus for each item above, the threshold value must not exceed 0.2 (d≤0.2). The percentage of expert consensus must exceed 75%, whereas the defuzzification value for each item must exceed the α-cut value = 0.5. To obtain the threshold value, the distance between two Fuzzy numbers is determined using Equation 1.0

$$\mathrm{d}(\tilde{m}, \tilde{n}) = \sqrt{\frac{1}{3}\left[(m_1 - n_1)^2 + (m_2 - n_2)^2 + (m_3 - n_3)^2\right]}$$

Source (Mohd Ridhuan Mohd Jamil & Nurul Rabihah Mat Noh, 2020)

The results of expert consensus through the Fuzzy Delphi method showed that all the components and elements listed have expert consensus and comply with all the conditions in the Fuzzy Delphi method to be included in the development of the AR Module. From this Fuzzy Delphi analysis, it was found that the percentage of expert agreement on all items for the AR Module elements was 98%. This means that 98% of experts agreed that all components and elements should be included in the development of the AR Module. The percentage of items and the total percentage of expert agreement of more than 75% (> 75%) indicate that all items were accepted by the experts (Mohd Ridhuan & Nurulrabihah Mat Noh et al., 2020). Table 2 displays the percentage of expert agreement for the components of the AR Module.

Table 2. Percentage of Expert Agreement for the Components of the AR Module by Fuzzy Delphi Technique

	Item				
	1	2	3	4	5
No item d≤0.2	24	25	25	24	24
Percentage Each Item d≤0.2	96%	100%	100%	96%	96%
Total Item d≤0.2			122		
Total Percentage Item d≤0.2			98%		

3.3 Phase 2 DDR: Evaluation; (Effectiveness)

For the evaluation phase, the effectiveness of the AR Module was tested on the achievement of rural students in Malaysia in the Science subject. This experimental study utilised the quantitative approach using a sample consisting of 74 students in rural schools in Malaysia. The method of sample selection according to the treatment and control groups was random purposive sampling. The control group experienced conventional learning, while the treatment group was given an intervention: learning based on technological learning using AR. A true experimental study is a design approach used to examine significant comparisons or differences between the treatment and the control group. In such a study, samples are randomly selected to examine cause-and-effect relationships using control and treatment groups (Creswell, 2014). This research adopted an experimental design as it allows for testing and determining the causes of certain effects and identifying significant differences between two or more study variables. Figure 1 shows this study's design in greater detail.

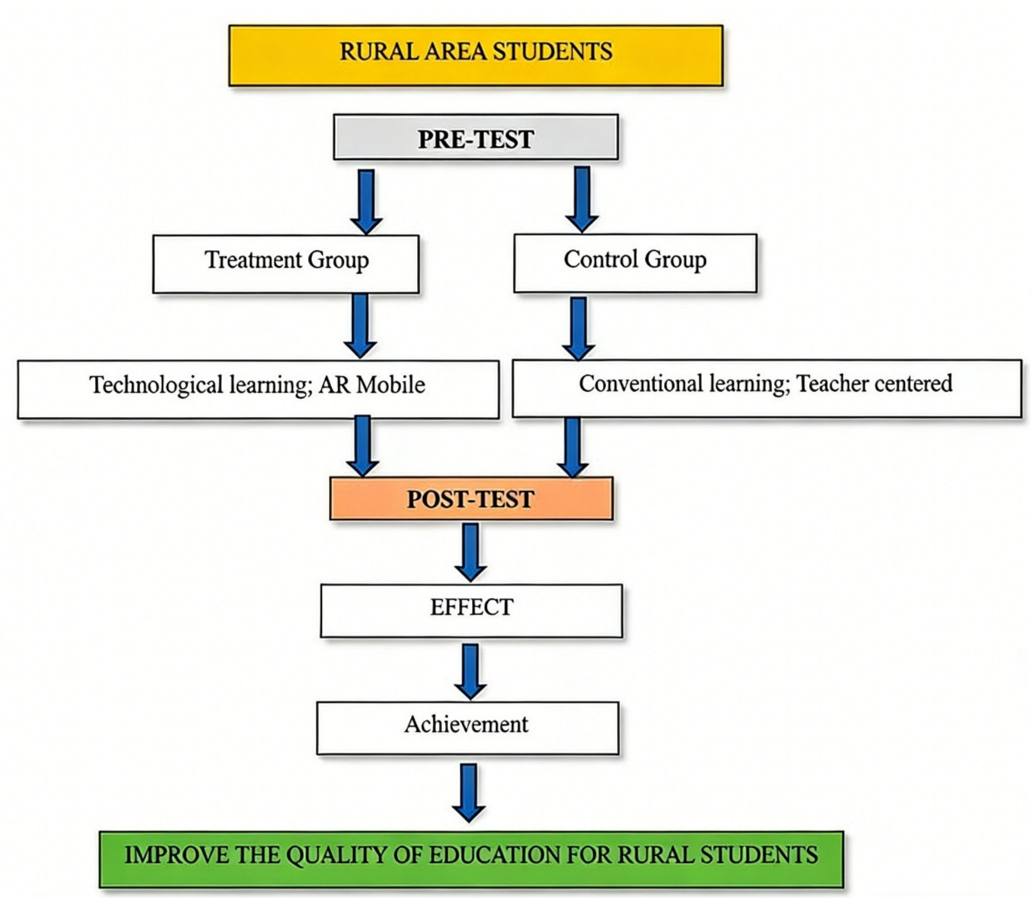

Figure 1. Research Flow Diagram

Each treatment and control group was given a pre-test and post-test to test the effect of technological learning in AR on student achievement. This coincides with Creswell (2014) stating that pre- and post-tests are very suitable to measure the effectiveness of a learning intervention against the treatment and control groups. In this study, they were used to determine the effect of learning the Science subject through the AR on student achievement. The sampling method for this study included stratified and simple random sampling. The population was divided into specific strata or subgroups before the samples were selected using simple random sampling. The population included 122 fifteen-year-old students from a specific rural area in Malaysia. Stratified random sampling was utilised to select 60% of the population as the study sample. Stratified random sampling is a highly suitable technique for research involving multiple categories and specific criteria (Creswell,2014). Subsequently, simple random sampling was conducted within the identified strata. A total of 74 students were selected as the sample, chosen through simple random sampling based on specific criteria using a lottery method. Each of the 74 students participated in a draw to determine whether they would be assigned to the treatment or the control group. The lottery method in simple random sampling ensures a fair selection process from among the population (Creswell, 2014).

4. Results

For this study, a quantitative data analysis method was introduced with experimental methods. ANOVA analysis was used to examine the differences between two distinct groups: the control group, which received conventional teaching, and the treatment group, which used AR Module applications in the learning of the Science subject. One-way ANOVA was used to make a comparison of students between the two treatment and control groups. The result showed that learning science through an AR application provides good effectiveness in improving student achievement, especially among rural students.

Table 3. Mean Score of Experimental Group & Control Group

Group	Sample	Mean	Std. Deviation	Std. Error
Treatment	37	64.7000	11.54442	2.58141
Control	37	52.6500	11.04191	2.46905
Total	74	58.6750	12.71056	2.00972

From Table 3, it can be observed that the achievement score for the treatment group was the highest, with a value of 64.7 (SD = 11.54, n = 37). On the other hand, the achievement score for the control group reached a value of 52.65 (SD = 11.04, n = 37). Based on the analysis, it can be observed that the mean of the treatment group was higher than that of the control group. Based on these findings, it can be concluded that learning using AR can improve the quality of education for rural students. Additionally, this method has shown better effectiveness in improving student achievement in science subjects for rural students.

Table 4. One-way ANOVA of Students' Achievement in Science: Experimental Group & Control Group

Group	Sum of square	df	Mean square	F	Sig
Between Groups	1452.025	1	1452.025	11.380	0.002
Within Groups	4848.750	72	67.344		
Total	6300.775	73			

Based on Table 4, a one-way ANOVA analysis was performed on student achievement based on the two treatment and control groups according to different learning approaches. The results of the one-way ANOVA test in Table 2 revealed a significant difference in student achievement according to different groups, with an F value (df = 72, $p < 0.02= 11.380$). This result reinforces the hypothesis that learning science through the use of AR applications is more effective for students' achievement and understanding compared to conventional learning. It may thus be concluded that learning using AR can improve the quality of education for rural students. Based on the findings of the study, the use of AR technology in teaching and learning has been proven to improve the quality of education among rural students, especially in science subjects. This approach provides a more interactive, visual, and contextual learning experience, thus helping students understand abstract concepts more deeply (Tsai, 2020). In line with this study, several researchers have shown that students exposed to AR-based learning displayed higher academic achievement compared to control groups using traditional methods (Wan Ab Kadir et al., 2023; Chen et al., 2022).

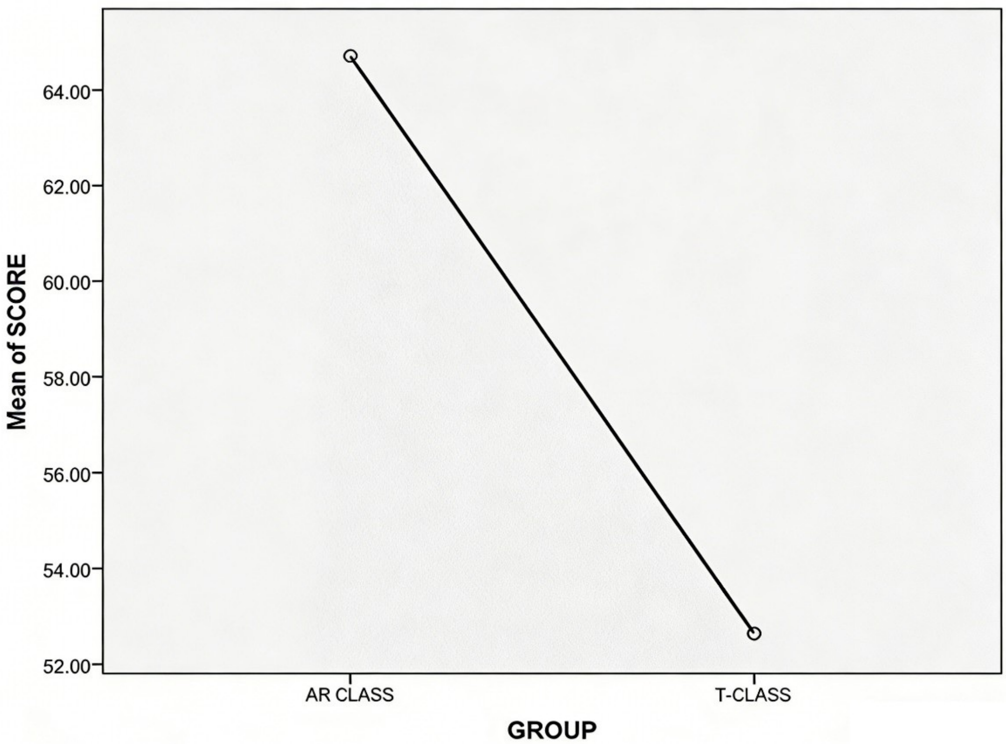

Figure 2. Means Plots of Student Achievement Between Treatment Group & Control Group

The Mean Plot (Figure 2) shows a smaller mean score of the control group than that of the treatment group. AR Class recorded a significantly higher mean score than T-Class, with a difference of 12.05 points. The graph shows a significant decrease from AR to T-Class, indicating the positive impact of learning using AR on student achievement. This significant mean difference demonstrates that Science learning based on AR applications can help improve rural students' achievement. Compared to traditional methods, AR has proven more effective in improving student understanding and performance by increasing engagement, visualising abstract concepts, and making learning more contextual and engaging among rural students.

5. Discussion

This study developed an AR Module for the Science subject, which included theoretical learning videos, experimental videos, exercises with feedback to students, and interesting quizzes with 3D animations. Based on the findings, it was found that learning Science through AR technology has many implications, especially for rural students. First, AR was seen to have the ability to help students with abstract concepts in Science. Rural students who may lack in terms of science learning infrastructure can understand abstract Science concepts through AR, which replaces expensive Science equipment. For example, the developed AR Module includes practical learning of the refractive index of glass, consisting of various tools and apparatus that can only be experienced through AR technology, without having various practical tools and apparatus. Additionally, Vidak et al. (2023) found that the use of AR in teaching Science can reduce cognitive load and increase mastery of abstract concepts.

Furthermore, it was revealed from this study that the adaptation of learning through AR in Science learning had improved achievement in Science, driven by the technological elements of the AR Module itself. Its attractive 3D animations and interactive learning features with quizzes containing descriptive feedback for students made learning effective. The module also made it easier for students to understand learning and subsequently improved student achievement in the Science subject. This finding is supported by Buditjahjanto and Irfansyah (2023), who showed that students who use AR displayed higher cognitive and psychomotor achievement compared to other learning methods.

This developed AR Module can produce equitable learning in terms of infrastructure. The use of mobile AR via smartphones or tablets can enable rural schools to implement interactive science learning despite the lack of infrastructure resources. Lin et al. (2023) found from their study that the mobile AR approach effectively reduced the digital gap between urban and rural students, with a significant increase in academic achievement, high-level cognition, and self-efficacy. It suggests that mobile AR can provide equitable access to interactive learning even though a specific area may have incomplete infrastructure. The findings of this study are also in line with research by Lin et al. (2023), which empirically demonstrated that mobile AR can effectively reach rural students without the need for physical laboratories or complete traditional infrastructure. Mobile technology that applies AR in teaching alone is sufficient to produce interactive learning without relying on very expensive physical resources.

However, the use of AR technology also faces several constraints that need to be addressed. For example, the lack of training and confidence of teachers in using AR technology causes their discomfort and rejection (Zhang et al., 2025; Wang et al., 2023). These problems further lead them to be less interested in conducting science teaching and learning sessions with the help of AR technology. In addition, there are constraints in terms of curriculum in rural schools in Malaysia, which are not always structured to support AR learning with proper coordination with science objectives (Zhang et al., 2025). Moreover, AR applications sometimes encounter problems with possible interruptions, such as animation stops, visual delays, or connection errors, which affect the learning process. This situation causes extraneous cognitive load, where students may focus on irrelevant elements of the interface, which will interfere with the construction of understanding of real science concepts (Zhang et al., 2025; Wang et al., 2023).

6. Conclusions

This study developed an Augmented Reality (AR) Module for the Science subject, which includes theoretical learning videos and experimental videos. Throughout this study, it was found that the achievement of rural students increased after experiencing AR technology-assisted Science learning. However, several gaps and constraints remain in AR teaching that need to be addressed by the authorities to improve the achievement of rural students in Science. Among them is giving emphasis and special training to rural teachers on AR learning, either through courses on how to produce AR learning or courses on how to operate AR-assisted learning. In addition, the module elements in AR learning itself need to be efficient, interactive, and interesting to attract rural students into learning Science and subsequently improve their understanding and achievement.

This article describes the development of the STEM Project: AR Module to improve the quality of education for rural students in Malaysia for the Science subject. AR technology is one of the important fields in the world of virtual reality and has attracted interest from various disciplines. It is a novel form of teaching media in educational technology that can enhance the overall educational application, especially for rural students. Learning with the AR Module has also proven to be more effective than traditional teacher-centred approaches, as it provides opportunities for students to explore more deeply and think creatively. In summary, it can be concluded that the use of AR applications can improve the understanding and achievement of rural students in science subjects in Malaysia. In addition, during this project, the researchers managed to observe the excitement of rural students experiencing more interesting science learning with 3-dimensional (3D) images and virtual objects that can simultaneously improve their understanding and academic achievement.

References

Abdul Hamid, N. H., & Chowopass, V. (2024). *The MalaysiaScience, Technology, Engineering, and Mathematics (STEM) Education Landscape Study* (Vol. 4, No. 2, July 2024).

Abdullah, S., Hassan, N., & Salleh, F. (2023). Enhancing Student Motivation in science Through Augmented Reality in Rural Schools. *Journal of Educational Technology.*

Alam, A. F. P., Suhendra, N., & Prabawanto, S. (2020). The factors that influence students' solution related to inverse proportion problems. *Journal of Physics Conference Series*, *1521*(3), 032081. https://doi.org/10.1088/1742-6596/1521/3/032081

Alamri, M. M., Almaiah, M. A., & Al-Rahmi, W. M. (2020). Social media applications Affecting Students' Academic performance: A model developed for Sustainability in Higher education. *Sustainability*, *12*(16), 6471. https://doi.org/10.3390/su12166471

Azhar, N., & Mustapha, A. (2021). Enhancing science learning through augmented reality in Malaysian secondary schools. International Journal of Learning and Teaching Innovation, 4(2), 123-134. https://doi.org/10.1234/ijlt.2021.0042

Buditjahjanto, I., & Irfansyah, E. (2023). *Improving students' cognitive and psychomotor abilities using augmented* *reality and their relationship to creativity*. Journal of Technology and Science Education, 13(2), 548-559. https://doi.org/10.3926/jotse.1813

Chang, H., Binali, T., Liang, J., Chiou, G., Cheng, K., Lee, S. W., & Tsai, C. (2022). Ten years of augmented reality in education: A meta-analysis of (quasi-) experimental studies to investigate the impact. *Computers & Education*, *191*, 104641. https://doi.org/10.1016/j.compedu.2022.104641

Chen, C. H., Chen, M. P., & Tsai, Y. S. (2022). Investigating the effects of augmented reality-based learning environments on students' science learning outcomes: A meta-analysis. *Educational Technology Research and Development*, *70*, 395-421. https://doi.org/10.1007/s11423-021-10061-0

Chen, G., Wang, J., Chen, Y., & Chi, Y. (2025). An augmented reality-based experiential learning approach to science education.

Chong, A., & Rahman, Z. (2023). The Role of Augmented Reality in Bridging Educational Gaps in Rural Malaysia. *International Journal of Rural Education*.

Chong, S. K., Lee, J., & Nor, Z. (2021). Augmented Reality in science Education: A Study in Malaysian Rural Schools. *MalaysiaJournal of science Educatio*n.

Creswell, J. W. (2014). *Research Design: Qualitative, Quantitative and Mixed Methods Approaches* (4th ed.). Thousand Oaks, CA: Sage. https://doi.org/10.5539/ELT.V12N5P40

Dewey, J. (1899). *The school and society*. Retrieved from http://ci.nii.ac.jp/ncid/BA05324648

Halim, M. F., Ahmad, Z., & Hassan, R. (2022). The impact of augmented reality on students' science achievement in secondary schools. *Journal of Educational Technology and science, 8*(3), 45-58. https://doi.org/10.1016/j.jetsci.2022.03.007

Hanis, N. M., Jamil, M. R. M., Yulu, J., Zalli, M. M. M., & Othman, M. S. (2025b). Design and Development Research (DDR) approach in development of Value-Based Pedagogy Model in the context of a Multiracial Country. *Journal of Curriculum and Teaching*, *14*(1), 248. https://doi.org/10.5430/jct.v14n1p248

Hasmiza Yaakob et al. (2023). Masalah Pembelajaran Murid Sekolah Rendah Luar Bandar Dalam Mata Pelajaran Sains. *International Journal of Humanities Technology and Civilization, 8*(1), 22-35. https://doi.org/10.15282/ijhtc.v8i1.9400

Ibáñez, M. B., & Delgado-Kloos, C. (2018). Augmented reality for STEM learning: A systematic review. *Computers & Education, 123*, 109-123.

Isman, A. (2011). Instructional Design in Education: new model. *The Turkish Online Journal of Educational Technology*, *10*(1), 136-142. http://files.eric.ed.gov/fulltext/EJ926562.pdf

Kolb, D. A. (1984). *Experiential Learning: Experience as the Source of Learning and Development*. Englewood Cliffs, NJ: Prentice Hall.

Le, L. T. B., Tran, T. T., & Tran, N. H. (2021). Challenges to STEM education in Vietnamese high school contexts. *Heliyon*, *7*(12), e08649. https://doi.org/10.1016/j.heliyon.2021.e08649

Lin, X.-F., Jiang, J., Luo, G., Huang, X., Li, W., Zou, J., Wang, Z., & Hu, Q. (2023). Mitigating the urban-rural digital divide: A dual scaffolding-embedded mobile augmented reality learning approach in the post COVID-19 pandemic. *Educational Technology & Society, 26*(4), 108-122. https://doi.org/10.30191/ETS.202310_26(4).0008

Mansour, N., Aras, C., Staarman, J. K., & Verhulst, F. (2025). Embodied learning of science concepts through augmented reality technology. *Education and Information Technologies, 30*, 8245-8275.

McKillip, J. (1987). *Need analysis*. https://doi.org/10.4135/9781412985260

Mohd Ridhuan Mohd Jamil, & Nurul Rabihah Mat Noh. (2020). D*iversity Methodology in design research and development* (1st ed.). Shah Alam: Qaisar Prestige Resources.

Mohd Yusoff, M. F., & Ismail, N. (2024). Insights into cloud-based learning for students in rural areas: Disparities in infrastructure, socio-economic factors, and awareness. *Jurnal Pendidikan Digital & Teknologi*, *5*(1), 34-52. https://doi.org/10.1234/jpdt.2024.23064

Mustafa, F., Nguyen, H. T. M., & Gao, X. A. (2024). The challenges and solutions of technology integration in rural schools: A systematic literature review. *International Journal of Educational Research, 126*, 102380.

https://doi.org/10.1016/j.ijer.2024.102380

Na, H., & Yun, S. (2024). The effect of augmented reality on K-12 students' motivation: a meta-analysis. *Educational Technology Research and Development, 72*, 2989-3020. https://doi.org/10.1007/s11423-024-10385-7

Nordin, A., & Hamid, F. (2024). Leveraging AR for Digital Learning in Rural Schools: A Malaysian Case Study. Asian Journal of Education and Technology.

Othman, M., Cyril, N., Mangao, D. D., Ng, K. T., Sinniah, D. N., & Rajoo, M. (2022). Malaysiastudents' perspective in science and science education. *Dinamika: Jurnal Ilmiah Pendidikan Dasar, 14*(2), 91-111. https://doi.org/10.30595/dinamika/v14i2.13303

Phang, F. A., Mohd-Yusof, K., Syed Hassan, S. H., & Hassim, M. H. (2012, June). *Engineering Students' Perception on Learning through Cooperative Problem-based Learning (CPBL) for the First Time*. Paper presented at the 2012 ASEE Annual Conference & Exposition, San Antonio, TX, United States.

Piaget, J. (1951). *Play, dreams and imitation in childhood*. https://ci.nii.ac.jp/ncid/BA45214929

Piaget, J. (2005). The Psychology of Intelligence. In *Routledge eBooks*. https://doi.org/10.4324/9780203981528

Rahim, M., & Yusof, R. (2022). Overcoming Educational Resource Limitations through Augmented Reality in Rural Malaysia. *Journal of science and Technology Education*.

Richey, R. C., & Klein, J. D. (2007). *Design and development research: Methods, strategies, and issues*. Routledge.

Richey, R. C., & Klein, J. D. (2014). Design and Development Research. In *Handbook of Research on Educational Communications and Technology* (pp. 141-150). New York, NY: Springer.

Salame, A. H., Tengku Shahdan, T. S., Kayode, B. K., & Pek, L. S. (2025). Enhancing STEM education in rural schools through play activities: A scoping review. *International Journal on Studies in Education, 7*(1), 103-124. https://doi.org/10.46328/ijonse.293

Shamsudin, S., Rahman, M., & Yusof, R. (2023). Augmented reality in science education: A case study in Malaysian secondary schools. *Malaysian Journal of science Education, 12*(1), 98-114. https://doi.org/10.2139/mjsci.2023.000

Siraj, S., Abdullah, M. R. T. L., & Rozkee, R. M. (2020). *Pendekatan penyelidikan reka bentuk dan pembangunan*. Penerbit Universiti Pendidikan Sultan Idris.

Tsai, C. (2020). The effects of augmented reality to motivation and performance in EFL Vocabulary learning. *International Journal of Instruction*, *13*(4), 987-1000. https://doi.org/10.29333/iji.2020.13460a

Usher, C. L., & McKillip, J. (1988). Need analysis: Tools for the human services and education. *Contemporary Sociology a Journal of Reviews*, *17*(3), 369. https://doi.org/10.2307/2069663

Van den Berg, I., Admiraal, W., & Pilot, A. (2006). Design principles and outcomes of peer assessment in higher education. *Studies in Higher Education*, *31*(3), 341-356. https://doi.org/10.1080/03075070600680836

Vidak, A., Šapić, I. M., Mešić, V., & Gomzi, V. (2023). Augmented Reality Technology in Teaching about Physics: A systematic review of opportunities and challenges. *European Journal of Physics*, *45*(2), 023002. https://doi.org/10.1088/1361-6404/ad0e84

Vygotsky, L. (1978). *Mind in Society: the development of higher psychological processes*. https://ci.nii.ac.jp/ncid/BA03570814

Wan Ab Kadir, W. N. H., Abdullah, N. S. Y., & Mustapha, I. R. (2023). The effectiveness of Form Four STEM-based Physics Interactive Laboratory (i-Lab) by employing Isman Instructional Design Model. *Turkish Online Journal of Educational Technology (TOJET)*, *20*(2), 112-120.

Wang, X-N., Young, G. W., Iqbal, M. Z., & Mc Guckin, C. (2023). The potential of extended reality in rural education's future - perspectives from rural educators. *Education and Information Technologies, 29*(7), 8987-9011. https://doi.org/10.1007/s10639-023-12169-7

Zainal, A., Nor, H., & Aziz, R. (2023). Educational Technology for Rural Development: A Case Study in Malaysian Secondary Schools. *International Journal of Educational Development*

Zhang, S. F., & Yao, Z. (2025). The challenge of the application of augmented reality in science education in China: A systematic review. *Disciplinary and Interdisciplinary Science Education Research, 7*(4), Article 4.

https://doi.org/10.1186/s43031-025-00123-1

Zhang, Y., Mondal, H., & Singh, R. (2025). Adopting augmented reality and virtual reality in medical education in resource-limited settings: Constraints and the way forward. *Advances in Physiology Education*, *49*(2), 1043-4046. https://doi.org/10.1152/advan.00027.2025 researchgate.net+7

Ziden, A. A., Ziden, A. a. A., & Ifedayo, A. E. (2022b). Effectiveness of augmented reality (AR) on students' achievement and motivation in learning science. *Eurasia Journal of Mathematics Science and Technology Education*, *18*(4), em2097. https://doi.org/10.29333/ejmste/11923

Acknowledgments

This research was supported by The Ministry of Higher Education [MoHE] through Early Career Researcher [FRGS-EC/1/2024/SS109/UPSI/02/36] and Sultan Idris Education University, Malaysia.

Authors contributions

Not applicable.

Funding

This research was supported by The Ministry of Higher Education [MoHE] through Early Career Researcher [FRGS-EC/1/2024/SS109/UPSI/02/36] and Sultan Idris Education University, Malaysia.

Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Informed consent

Obtained.

Ethics approval

The Publication Ethics Committee of the Sciedu Press.

The journal's policies adhere to the Core Practices established by the Committee on Publication Ethics (COPE).

Provenance and peer review

Not commissioned; externally double-blind peer reviewed.

Data availability statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Data sharing statement

No additional data are available.