JOURNAL OF CULTURAL ANALYSIS AND SOCIAL CHANGE

Journal of Cultural Analysis and Social Change,
2025, 10(2), 3214-3221
ISSN: 2589-1316

The Efficacy of Augmented Reality (AR) Gamification in Enhancing Motivation and Academic Performance among Primary School Students in Malaysia when Learning about the Topic of Energy

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Citation: Murti, S. B. A/P., Islaieh, A. I. S., Hussin, U. S. B. M., Bin, R. Usop., Amin, A. F. M. and Mohamad, M. (2025). The Efficacy of Augmented Reality (AR) Gamification in Enhancing Motivation and Academic Performance among Primary School Students in Malaysia when Learning about the Topic of Energy, *Journal of Cultural Analysis and Social Change*, 10(2), 3214-3221. https://doi.org/10. 10.64753/jcasc.v10i2.2084

Published: November 19, 2025

ABSTRACT

Augmented Reality (AR) can increase student motivation, awareness, and accomplishment in learning Energy, a science subject. As such, this study aims to examine the use of AR gamification to teach this subject to grade 4 students in primary school. Many of them are less drawn to AR, which requires a high level of imagination to understand its various dimensions. Smartphones have a limited number of education-based applications that can facilitate the comprehension of Science, Technology, Engineering, and Mathematics (STEM). It proves crucial to develop a digital application that improves the motivation, as well as understanding and awareness of energy among the younger generation. An energy learning application that combines AR and gamification was used to examine its efficacy in improving student motivation and academic performance in the context of energy.

Keywords: Augmented Reality (AR), Gamification, Primary School, Topic of Energy

INTRODUCTION

The AR allows for integrating the tangible and virtual elements in an interactive and real-time manner. Various educational applications incorporate the use of AR in their designs. In European countries, the AR Marine Scientific initiative aims at advancing high school students' comprehension of the marine environment. This application is key to improving the academic performance of pupils who do not fulfil expectations. Moreover, the use of both AR and printed books in evaluating and contrasting Biology students' learning significantly improved Biology learning (Lase, 2019).

Several AR applications involve the use of a gamification aspect to actively involve learners in the educational process. Avid players, most of whom belong to the younger demographic segment, are more likely to engage in games. In this vein, a robust educational instrument that integrates AR technology and gamification in its application design can optimise students' learning outcomes (Volioti et al., 2022). These applications positively contribute to students' learning performance, particularly in challenging or less engaging subjects. An advanced AR game, ATHYNOS, is specifically designed to assist students with dyscalculia in acquiring mathematical skills. The children who used this application required less time to understand the lesson taught. Furthermore, a new software was created to gain knowledge about a complex writing system known as kanji. Dragon Tale (AR), an educational video game, was developed to promote interactive kanji learning among children. Another study was performed to facilitate Thai students' acquisition of a similar writing system. In particular, the researchers developed an AR application that improves the ability to read and write kanji characters by a significant margin of over 41% (Ramli et al., 2021).

The AR technology is a sophisticated instructional approach that offers contextualised and embodied learning experiences by overlaying virtual data over the real world. Despite extensive research performed in educational contexts, studies on AR remain underexamined. The current work proposed the development of an instructional platform for grade 4 primary school students to understand the subject of Energy.

Educational scholars, physicists, and teachers have extensively discussed the most suitable approach for instructing this subject (Razali et al., 2021). Lins (2012) utilised eco-friendly educational resources to advance the understanding of energy preservation and the subsequent reduction of CO2 emissions. Meanwhile, Lee et al. (2012) created a practical educational exercise with low-energy house models designed for elementary school children. Liu, Chen, Chiu and Lais (2012), who incorporated models of green buildings, discovered an increase in knowledge scores. In employing five demonstration devices during energy education courses, Ou et al. (2007) revealed a statistically significant increase in children's knowledge scores following the lectures. Takaki et al. (2007) examined the impact of the instructional materials by creating an energy and environment curriculum for elementary schools in Japan (B. Liu, 2021).

Past works have highlighted positive outcomes when employing problem-based learning (PBL) to acquire knowledge about energy. For example, research on the implementation of a tide monitoring project involving high school students revealed an increase in understanding of ecology and their abilities in scientific investigation (Baumgartner & Zabin, 2008; Ponniah, 2016). Turkish frontline teachers introduced problem-based learning to foster environmentally-conscious behaviours. As evidenced by Ozvoldova and Gerhatova (2013), using the same approach to teach energy concepts advanced grade 9 students' comprehension of real-life applications.

Carrier, Tugurian and Thomson's (2013) use of an outdoor experiential method disclosed that primary school pupils develop more favourable attitudes towards the environment. Meanwhile, students in the United States gained more knowledge of the cause-effect relationships between heat transfer and energy efficiency via a computer-aided design programme called Energy 3D (Dasgupta, Magana & Vieira, 2019).

Based on Chen et al. (2021), the implementation of an AR gamification method increased the engagement and motivation of students studying renewable energy. Huang et al. (2020) examined the effects of an AR gamification application on students' understanding and actions related to energy in daily life. Furthermore, Zawawi et al. (2019) developed an AR game to educate students on energy conservation.

Problem Statement

This study aimed to examine AR gamification's efficacy in increasing Malaysian primary school students' motivation and academic performance in energy education. In education, gamification involves the strategic integration of game-like components (prizes, competition, and feedback) into non-game settings (the curriculum) to foster engagement, motivation, and academic achievement in the learning process (Kapp, 2012; Zichermann & Cunningham, 2011). The AR technology superimposes digital information onto the physical environment to provide a more immersive and interactive learning environment that improves student involvement and enthusiasm in the knowledge acquisition process (Wu, Lee, Chang & Liang, 2013). In the Malaysian primary school curriculum, students find energy education to be challenging due to its abstract and complex elements (Koponen, Nousiainen & Lavonen, 2016). Nurulhuda, Alias and Yusof (2020) demonstrated that using AR gamification in energy concept instruction increases students' comprehension and academic achievement. Based on Mohd Zaid et al. (2019), the implementation of AR gamification was found to increase students' motivation and engagement levels in science education. Hence, it is imperative to examine the efficacy of AR gamification in enhancing student engagement, motivation, curiosity, and understanding of energy concepts for improved academic performance.

Research Objective

This study aimed to assess the efficacy of AR gamification based on the following objectives:

- To assess the efficacy of AR gamification in enhancing student performance in the subject of Energy.
- To assess the efficacy of AR gamification in enhancing student motivation in learning about the subject of Energy.
- To assess the efficacy of AR gamification in enhancing students' awareness of energy.

Research Questions

The research questions parallel the study aims.

- To what degree does the usability of AR gamification assist teachers in implementing teaching and learning methodologies in the subject of Energy?
- What is the impact of AR Gamification on students' achievement in the area of Energy?
- Is there a substantial disparity in the accomplishment between students who utilise AR gamification in their learning and students who engage in conventional learning methods?
- What is the level of effectiveness of AR gamification in enhancing students' motivation in learning about the subject of Energy?
- Is there a notable disparity in motivation between students who utilise AR gamification in their learning and students who engage in conventional learning?
- What is the level of effectiveness of AR gamification in increasing students' awareness of energy?
- Is there a notable disparity in energy awareness between students who utilise AR gamification in their learning and students who engage in conventional learning methods?

LITERATURE REVIEW

The AR is a continuous process that has evolved over time and garnered much popularity. On a global scale, the number of mobile AR users is estimated to reach 1.7 billion by 2024. This technology was initially employed as a scientific tool and then integrated into the learning process as a modern educational instrument (Shukri et al., 2020). In this vein, AR technology is a key catalyst for student motivation in educational settings (Karagozlu, 2021).

In line with educational principles, the motivation to learn positively contributes to learning performance. The AR improves motivation, involvement, and the development of problem-solving, observation, and exploration abilities. As such, AR should be incorporated as a key component of modern instructional practices. This sophisticated technology, which combines interactivity with prompt feedback, can revolutionise specific educational approaches. Educational AR tools use gamified concepts, which can significantly affect students' motivation and knowledge acquisition in the learning process.

Recent scholars have examined the use and benefits of AR in diverse environments. Regarding English instruction in secondary school, Kucuk et al. (2023) investigated the motives, attitudes, and achievements related to the use of AR technology alongside conventional textbooks. Resultantly, students demonstrated favourable attitudes toward the integration of AR and conventional textbooks. The amalgamation led to increased motivation and learning performance. In this regard, students encounter less difficulties in acquiring knowledge. Serio et al. (2016), who undertook a course and study on the subject of visual arts, used an AR application to display images of Italian Renaissance art. The implementation of AR significantly increased students' attention, relevance, confidence, and satisfaction compared to conventional learning.

Huang et al. (2017) examined the practicality of incorporating AR technology into early art education. In line with Marouli (2021), children found the use of AR applications to be enjoyable, thus increasing their involvement and creativity. Teachers' inclination to integrate AR applications into their daily teaching reflects their positive view of AR a valuable teaching instrument.

Advantages of AR in Education

The AR technology has gained much popularity in STEM, specifically in K-12 education (Department of Education, 2015). In essence, STEM applications rely on knowledge discovery via interactive engagement using 3D augmented objects supported by common mechanisms, design patterns, and features. This technology is commonly used to incorporate tangible items (manipulatives) in mathematics education (Thamrongrat, 2021).

Similarly, AR tools have been rapidly incorporated into educational settings. The AR technologies in geometry offer a broad range of attributes, including sophisticated 3D geometric shapes and objects, as well as real-time transformations. These capabilities optimise participants' inquiry-based learning. Kaufmann and Schmalstieg specifically designed a 3D geometric design programme called Construct 3D for high school students (Thamrongrat, 2021). Various AR products have been designed to educate individuals in procedural or object-oriented programming. For example, Fuste and Schmandt (2019) developed Hypercubes, an AR platform that promotes computational thinking and the comprehension of procedural programming (Lu et al., 2021).

Integrating AR with paper cubes increases students' spatial abilities and exposes them to the principles of instructions and sequences. This technology provides visual representations of a robot's internal workings via simplified robot programming. Students can observe a robot's sensor data in real-time by iteratively refining their code based on the robot's behaviour.

The AR in Science Education

Fleck and Simon (2019) conducted an experiment based on primary school astronomy classrooms to facilitate students' development of scientific knowledge about the solar system and clarify misunderstandings about basic astronomical concepts. An exploratory investigation was also conducted based on the principles of inquiry-based scientific education (Ramli et al., 2021), where two physical 3D models related to astronomy were compared. One model was enhanced with an AR model, while the other was a conventional physical model. Based on B. Liu (2021), students favoured the AR model over the standard 3D one to realistically modify and shift the celestial bodies based on their viewpoint.

The individuals who used AR demonstrated a higher level of proficiency in key scientific topics and enhanced learning outcomes. Zhang et al. (2014) developed an AR mobile digital armillary sphere for studying astronomy by providing an alternative method for kinaesthetic learning. While the implementation of astronomy can be challenging in classrooms due to space or time constraints, the AR observation tool facilitated the manipulation of astronomical concepts for grade 5 students to identify and explore constellations. The participants enhanced their scientific imagination and drive to acquire knowledge, learning experience, and observational skills (Sofianidis, 2022).

Cai et al. (2014) developed an AR simulation system for middle school students to use in their chemistry lectures. These individuals can manipulate and merge 3D models of microparticles, conduct experiments, and construct substances within a simulated micro-environment. This pedagogical technique can impart basic knowledge about microworlds. Notably, the integration of AR with inquiry-based learning methods can increase learning achievements, foster positive attitudes towards concepts, and increasing problem-solving (Mohamed Noor et al., 2015).

Enyedy et al. (2022) developed a unified AR learning setting in physics, with emphasis on children between 6 and 8 years old. Newtonian principles related to force and motion were used in this study. The students were required to make predictions about the impact of specific forces on an object's movement. Cognitive principles were readily absorbed by engaging in this experiential learning, where the students functioned as mobile entities. Furthermore, the majority of children could gain a sound understanding of distinct forces. Students who actively interacted with AR technology demonstrated a notable enhancement in their understanding of extended forces. In this vein, the students could explore and reconstruct their conceptual knowledge using two-way interactions (Volioti et al., 2022).

Ariffin et al. (2020) experimented with convex imaging, which constitutes complex physical principles such as image distance and focus mapping, as well as abstract notions on the behaviour of objects as they approach a lens. The experiment involved the participation of grade 8 students. Students who used AR tools were able to establish a meaningful correlation between their responses and understanding. Scenarios involving the use of AR could improve students' learning outcomes and engagement levels. Zafeiropoulou et al. (2021) presented a game-based AR learning system designed to teach physics to grade 5 primary school students. Physics experiments were conducted by involving students in a treasure hunt game. Following the initial outcomes, the AR system proved functional and captivating for both students and teachers (E. Liu et al., 2019).

Mora et al. (2018) employed the Kinect motion sensor to develop an AR system for instructing grade 8 students on the topic of magnetic fields. Students could activate the magnetic field through real-time hand movements using a Kinect depth camera. In line with Volioti et al. (2022), the students' experience was more realistic compared to other computer simulation programmes based on flash technology.

Participants' learning and motivation increase with a more instinctive approach that offers prompt feedback. Pittman and LaVi-ola (2020) qualitatively assessed the effects and opinions about the possible implementation of AR in advanced physics courses. A prototype application, known as PhyAR, was developed using Unity3D and the Microsoft HoloLens device. This application provides demonstrations of complex physics concepts, including Coulomb's law, elastic collision, parallel circuits, volume, magnetic fields, and the Doppler effect. The findings revealed a distinct preference for novel physics-driven technologies based on AR (Volioti et al., 2022).

Challenges and Solutions in AR Implementation

The integration of AR technologies with pedagogical approaches can offer an educational experience that increases learning achievements. Notwithstanding, these technologies have certain limits resulting from the requisite technological skill. Regardless the use of AR applications, Tobar-Muoz et al. (2016) revealed that cooperating individuals often demonstrate disparities in their competence in producing learning experiences. Professional game creators lack exposure to the actual classroom setting and pedagogical methods employed. Furthermore, teachers often lack the specialised knowledge and time to develop AR applications. From the instructors' standpoint, these challenges may cause reluctance to implement AR in the classrooms. All individuals must be involved in the educational process to receive adequate training on the use and development of optimal learning experiences, as well as develop a suitable AR pedagogical tool (Godoy, 2020).

Several studies on AR implementation have been conducted in Malaysian classrooms. A study involving a group of nine primary school students and one instructor was conducted using an AR application driven by gamification components to enhance the students' understanding of microorganisms. Another empirical work aimed to examine the effects of using AR on the educational achievement of 20 primary level students from a public school in relation to the solar system. A separate study entailing 66 university students was performed to investigate the individuals' perspectives on using AR and gamification to develop educational experiences that promote active and collaborative learning. A separate study examined the role of instructional design in facilitating the development of mobile AR applications with 87 university students. These applications aim to create creative learning environments that increase student involvement. Furthermore, Lampropoulos et al. (2022) investigated the capacity of AR games in enhancing game-based learning based on 150 participants.

The Application of AR in Education

A robust educational application should incorporate several media forms, including video, music, images, text, and animation, to increase students' interest. Avoidance of lengthy and intricate material is highly recommended. Activating the 3D aspect through AR feature can promote the enjoyment and engagement in the learning process. It is also crucial to assess the students' comprehension. Hence, interrogations or assessments must be incorporated into every programme module. Given the strong association between games and the younger generation, the evaluation be designed as a competitive game that allows students to compete against other players (Ramli et al., 2021).

The AR gamification has gained much traction in education and educational research in the last decade. Incorporating technologies such as AR into the science education learning environment is crucial for modern educational disciplines. Failing to do so could negatively impact productivity and learning outcomes. Nevertheless, AR's educational merits in the field of science extend beyond AR technology to include its design, implementation, and integration into formal and informal learning environments (Lampropoulos et al., 2022).

RESEARCH METHODOLOGY

A quasi-experimental approach was used to examine AR gamification's efficacy in enhancing student achievement and motivation in learning energy-related topics. This study design is frequently employed in educational research to assess the efficacy of interventions and provide additional resources for specific challenges. It allows for gathering extensive data from diverse sources and approaches, as well as comprehending the subject matter (Creswell & David Creswell, 2018).

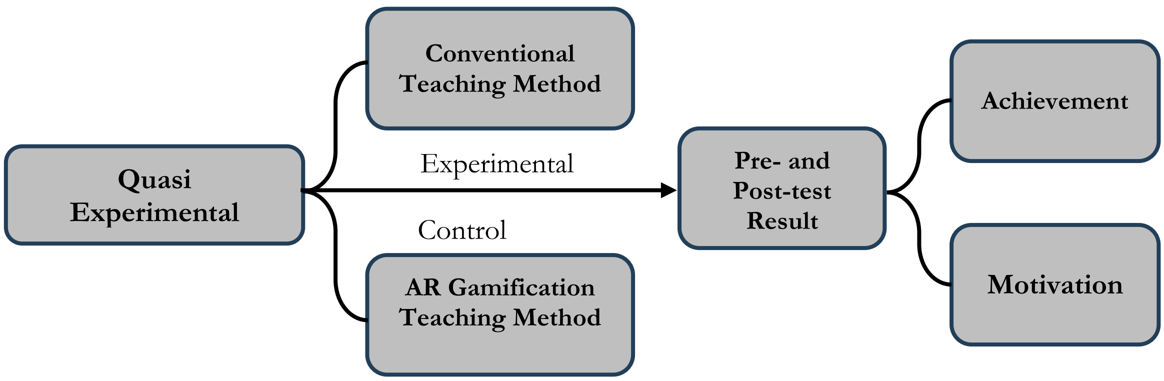

Figure 1: A Quasi-Experimental Design

A non-random sample is selected when the experimental or control group has no equal features (Cresswell, 2012). In this study, a sample encompassing students from a certain class was chosen without altering the existing class order. A pre-test was conducted following Cresswell (2012) to modify the instrument and increase the similarity between the two groups (Creswell & David Creswell, 2018).

Consequently, the AR gamification efficacy was assessed in two schools. Two teachers were chosen via deliberate sampling to execute teaching and learning methods in actual classrooms. Quantitative data were gathered from questionnaires, as well as pre- and post-tests, all of which were addressed by 60 students from two schools. A total of 30 students were instructed to use the project-based learning approach without AR gamification, while another 30 were asked to use the learning approach with AR gamification. Following the minimal disparity in pre-test scores between these two groups, the kids in the group demonstrated comparable attributes. The control group received the traditional teaching-learning method, while the experimental group received the AR gamification method.

This research, encompassing specific objectives and methodologies for each of the three phases, assessed the effectiveness of AR gamification on student achievement, motivation, and energy awareness in relation to energy.

Phase 1: Design and Development

This phase primarily aims to evaluate AR gamification's effectiveness on student achievement in the Energy subject. Sixty sample students were randomly assigned to a treatment group (n = 30) that received AR gamification or a control group (n = 30) that received none. A set of test questions were developed to assess student achievement. Empirical data were evaluated using SPSS to determine AR gamification's effect on student performance.

Phase 2: Student-focused Interviews

The second objective involves assessing AR gamification's effectiveness on student motivation in learning energy concepts. Ten students were selected to participate in student-focused interviews to yield insights into students' motivational levels. The interview data were thematically analysed to identify common patterns in student responses.

Phase 3: Student Reflection

The third objective involves assessing AR gamification's effectiveness on student energy awareness. Ten students were asked to answer the Energy Literacy Survey from Clarkson University following the use of AR gamification. The empirical data elicited from these reflections and survey responses were evaluated to assess the changes in student energy awareness.

A set of 30 participants was randomly assigned to the treatment and control groups. Both groups underwent a pre-test on energy prior to the lesson and a post-test to assess their achievement after the training.

Energy Quest AR was employed to examine different energy sources and gain knowledge about their benefits and drawbacks. Students in the treatment group were required to download and activate this application to launch a global map interface. Every site was linked to an energy source. The students could choose a specific place and pan the camera toward the ground to initiate the AR encounter.

Users can rotate the model, adjust the zoom level, and examine the 3D representation from different perspectives. Notably, the student could obtain textual and auditory information from the teacher during the exploration of the energy source. This material covered the source benefits and drawbacks, its function, as well as its environmental impact. The students could participate a quiz on the energy source to evaluate their understanding and accrue points for investigating various energy sources and successfully completing quizzes. Furthermore, the students could compare their scores with their friends on a leaderboard.

Students can receive badges by investigating all energy sources, providing accurate answers to all quiz questions, or promoting the application to their friends. They can also acquire virtual goods (energy-conserving devices or photovoltaic modules) that can be used to construct a simulated residence.

RESULTS

The pre-test scores of both the groups were deemed similar ($t = 0.62$, $p = 0.54$). Based on the instruction, the treatment group demonstrated an average post-test score of 85.5 with a standard deviation of 5.2. Conversely, the control group reflected an average post-test score of 78.2 with a standard deviation of 4.8.

The average pre-test scores were 40.1 (with a standard deviation of 3.6) for the treatment group and 40.3 (with a standard deviation of 3.4) for the control group. Meanwhile, the average post-test scores were 85.5 (with a standard deviation of 5.2) for the treatment group and 78.2 (with a standard deviation of 4.8) for the control group. The post-test scores were elicited to follow a normal distribution following the Shapiro-Wilk test results, with a p-value exceeding 0.05. An independent samples t-test revealed the average post-test score of the treatment group to surpass that of the control group ($t(58) = 5.34$, $p < 0.001$). The paired samples t-test revealed a statistically significant difference in mean scores between the pretest and post-test for both the treatment group ($t(29) = 32.12$, $p < 0.001$) and the control group ($t(29) = 18.54$, $p < 0.001$).

Notably, the treatment group achieved higher scores than the control group on the post-test, specifically in relation to energy. The treatment group reflected a considerably higher mean post-test score than the control group. Furthermore, both the groups demonstrated considerable improvement from pre-test to post-test. The use of AR gamification as a teaching tool was found to improve student achievement in the subject of Energy.

Both the groups participated in a student-driven interview regarding their motivation towards learning about energy. The treatment group revealed higher student motivation and knowledge levels than the control group. The former also exhibited increased engagement, curiosity, and enjoyment levels in relation to the learning experience.

Both the treatment and control groups were required to complete the Energy Literacy Questionnaire to assess their understanding, beliefs, and actions regarding energy. The treatment group possessed a better grasp of energy sources, conservation, and efficiency, with a more favourable disposition towards energy preservation actions than the control group.

DISCUSSION

The experimental group demonstrated superior accomplishment scores compared to the control group. Implementing AR gamification also increased student motivation when learning about the subject. For example, the experimental group reported higher levels of motivation than the control group.

This technology significantly increased students' awareness of energy. Based on the elicited outcomes, energy awareness scores in the experimental group were significantly higher than the control group.

Students highlighted AR gamification as an engaging method for acquiring knowledge about different energy sources. Through AR, these individuals can actively engage with 3D representations to advance their understanding of the benefits and drawbacks related to each source. The platform's incorporation of quizzes, leaderboards, badges, and virtual incentives offers a gamified learning experience that maintains player engagement and motivation.

Teachers can incorporate AR gamification into their instruction for improved learning outcomes and adopting sustainable energy practices.

CONCLUSION

The AR gamification can increase the motivation and academic performance of Malaysian primary school pupils learning about energy-related topics. Incorporating AR gamification in the classroom can increase interactivity and immersion, both of which improve students' comprehension and long-term memory of the lesson taught. Overall, AR gamification can benefit educators aiming to increase learning achievements and enthusiasm for STEM subjects among primary school students.

ACKNOWLEDGEMENT

The researchers thank the USIM Research and Innovation Management Centre, as well as the instructors and students who participated in this survey.

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