



Assessing Adolescents' Satisfaction Level with Learning Through an Augmented Reality Application for Promoting Physical Activity

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Abstract: Objective : Physical inactivity among adolescents remains a major global concern, with approximately 80% failing to meet the World Health Organization (WHO) recommendation of at least 60 minutes of moderate-to-vigorous physical activity per day. This study aimed to evaluate adolescents' satisfaction level with learning about physical activity through an Augmented Reality (AR) application compared to traditional PowerPoint-based materials. **Methodology:** A quasi-experimental design was employed involving 60 secondary school students randomly assigned to two groups. The experimental group (n = 30) used the AR-based learning application, while the control group (n = 30) received similar content via PowerPoint slides. Data were collected using a satisfaction questionnaire consisting of four dimensions—ease of use, engagement, motivation, and overall satisfaction—and analyzed using the Mann–Whitney U test. **Key Findings:** Findings revealed significantly higher satisfaction among the AR group compared to the PowerPoint group ($p < 0.05$). Participants reported that AR learning was more interactive, enjoyable, and easier to understand. **Conclusions:** The results suggest that AR can enhance adolescents' satisfaction and motivation in learning about physical activity by providing immersive, interactive, and realistic visualizations. **Recommendations:** This study highlights the potential of AR technology as an engaging educational tool to promote active and healthy behaviors among youth.

Keywords : Augmented Reality, Physical Activity, Adolescents, Satisfaction

تقييم مستوى رضا المراهقين عن التعلم باستخدام تطبيق الواقع المعزز لتعزيز النشاط البدني

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الملخص الهدف: لا يزال انخفاض مستوى النشاط البدني بين المراهقين يمثل مصدر قلق عالمي رئيس، حيث إن نحو 80٪ منهم لا يحققون توصية منظمة الصحة العالمية بممارسة ما لا يقل عن 60 دقيقة من النشاط البدني المعتدل إلى مرتفع الشدة يوميًا. هدفت هذه الدراسة إلى تقييم مستوى رضا المراهقين عن تعلم النشاط البدني باستخدام تطبيق قائم على تقنية الواقع المعزز، مقارنة بالمواد التعليمية التقليدية المعتمدة على برنامج باوربوينت. **المنهج:** استُخدم تصميم شبه تجريبي شمل 60 طالبًا من المرحلة = تطبيقًا تعليميًا قائمًا على تقنية الواقع المعزز، في حين تلقت المجموعة الضابطة (30 = n) (30) الثانوية، وُزِعوا عشوائيًا إلى مجموعتين. استخدمت المجموعة التجريبية المحتوى نفسه من خلال عروض برنامج باوربوينت. جُمعت البيانات باستخدام استبانة لقياس مستوى الرضا، تضمنت أربعة أبعاد هي: سهولة الاستخدام، والتفاعل (n) والدافعية، والرضا العام، وحُلَّت البيانات باستخدام اختبار مان-ويتني. **أهم النتائج:** أظهرت النتائج ارتفاع مستوى الرضا لدى المجموعة التي استخدمت تقنية الواقع المعزز. وأفاد المشاركون بأن التعلم باستخدام الواقع المعزز كان أكثر تفاعلية ومتعة وأسهل فهمًا ($0.05 > p$) مقارنة بمجموعة الباوربوينت، مع وجود فروق ذات دلالة إحصائية. **الاستنتاجات:** تشير النتائج إلى أن تقنية الواقع المعزز يمكن أن تعزز مستوى رضا المراهقين ودافعيتهم نحو تعلم النشاط البدني من خلال توفير تصورات بصرية غامرة وتفاعلية وواقعية. **التوصيات:** تسلط هذه الدراسة الضوء على الإمكانيات التي توفرها تقنية الواقع المعزز بوصفها أداة تعليمية جاذبة لتعزيز السلوكيات النشطة والصحية لدى الشباب.

الكلمات المفتاحية: الواقع المعزز، النشاط البدني، المراهقون، الرضا

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Introduction

Physical inactivity among adolescents has become a major global concern, with nearly 80% failing to meet the World Health Organization's (WHO) recommendation of at least 60 minutes of daily moderate-to-vigorous physical activity (WHO, 2020). In Indonesia, approximately 57% of children also experience insufficient physical activity (Hanifah et al., 2023). This sedentary lifestyle is associated with increased risks of non-communicable diseases, mental health problems, and reduced cognitive development (Kumar et al., 2015; WHO, 2020).

Traditional approaches to promoting physical activity among adolescents have shown limited effectiveness due to excessive screen time and other lifestyle challenges (Time, 2019). Consequently, innovative approaches such as Augmented Reality (AR) have gained attention in education and health promotion. AR integrates digital content with the real environment to create interactive and immersive learning experiences that can improve motivation and engagement (Y. Chen et al., 2019; Garrett et al., 2018). Previous studies have shown that AR enhances physical education by supporting visualization and interaction through 3D models, thereby improving learning motivation, motor skills, usability, and willingness to participate in physical activities (Burns et al., 2022; Calabuig-Moreno et al., 2020; Liang et al., 2023).

Background

Augmented Reality (AR) has increasingly been used to promote healthy behaviors beyond physical exercise. In nutrition education, AR improves understanding of healthy eating by enabling visualization of calorie values, food composition, and portion sizes (Kulpy & Bekaroo, 2017; Paramita et al., 2021). Studies show that AR enhances engagement, comprehension, health awareness, motivation, achievement, interest, and learning outcomes compared with conventional approaches (Henchoz et al.,

2019; Tomczyk & Gottschalk, 2024). However, limited research has explored adolescents' satisfaction with AR-based health learning, despite satisfaction being closely linked to technology acceptance, motivation, and long-term behavioral adherence (Mittmann et al., 2022; Tomczyk & Gottschalk, 2024).

This issue is significant because more than 80% of adolescents globally and over 70% in Indonesia do not achieve recommended physical activity levels (Kementerian Kesehatan RI, 2023; WHO, 2020). Sedentary lifestyles and reliance on conventional health education methods, such as lectures and PowerPoint presentations, continue to limit engagement and behavior change (Paramita et al., 2021; Rahmi et al., 2021; Sekti & Fayasari, 2019; Time, 2019). Since adolescent habits influence long-term health outcomes, integrating AR into health education supports innovative strategies to encourage active lifestyles and improve learner satisfaction and sustained motivation (Fu et al., 2025; Janssen & LeBlanc, 2010; Mittmann et al., 2022; WHO, 2020).

Objectives

This study aims to:

1. Compare adolescents' satisfaction levels when learning about physical activity using an AR-based application and traditional PowerPoint materials.
2. Examine satisfaction across four dimensions—ease of use, engagement, motivation, and overall satisfaction.
3. Gather qualitative insights into adolescents' experiences and perceptions of the AR-based learning tool.

Research Questions

1. Is there a significant difference in overall satisfaction between the AR-based and PowerPoint-based learning groups?
2. How do the two groups differ across ease of use, engagement, motivation, and overall satisfaction?
3. What insights do adolescents' qualitative responses provide regarding their experiences with AR-based learning?

Boundaries

This study evaluated adolescents' satisfaction with AR-based learning for physical activity promotion and did not assess long-term behavioral change or physical fitness outcomes. The sample was limited to 60 secondary school students, which may affect generalizability. Satisfaction was measured only across ease of use, engagement, motivation, and overall satisfaction using self-reported questionnaires. The AR application was tested in a controlled digital environment using Assemblr, and results may have been influenced by factors such as internet stability, device specifications, and prior technology experience.

Literature Review

Physical Activity and Adolescent Health

Sedentary lifestyles driven by excessive screen time and digital entertainment are major contributors to low physical activity among adolescents, emphasizing the need for innovative and technology-based interventions to promote active living (Rahmi et al., 2021; Sekti & Fayasari, 2019). Adolescence is a critical developmental stage in which regular physical activity supports cardiovascular fitness, muscular and bone health, metabolic regulation, and reduces the risk of chronic and lifestyle-related diseases later in life (Janssen & LeBlanc, 2010; Kelley et al., 2022). Vigorous physical activity has been shown to provide greater physiological benefits than lower-intensity exercise, highlighting the importance of varied and engaging interventions for youth (Chaabene et al., 2024). Beyond physical health, physical activity enhances cognitive and mental well-being, with active adolescents demonstrating better executive function, memory, academic performance, and lower levels of anxiety, depression, and emotional distress (Adi et al., 2024; Biddle & Asare, 2011; Fu et al., 2025). Exercise interventions have also produced moderate-to-large

improvements in cognitive and psychological outcomes among youth (Biddle & Asare, 2011). Despite these benefits, fewer than one in four adolescents meet the recommended 60 minutes of daily moderate-to-vigorous physical activity (Azar, 2018), and prolonged sedentary behavior remains associated with increased cardiometabolic risk and lower well-being (Fu et al., 2025). Therefore, educational and policy initiatives should prioritize inclusive, engaging, and socially supported physical activity programs to encourage sustained participation and healthier adulthood outcomes (Chaabene et al., 2024).

Augmented Reality (AR) as an Educational Tool

Augmented Reality (AR) is an emerging technology that overlays digital content, such as text, images, and 3D models, onto real-world environments in real time (R. Chen & Karsen, 2025; Y. Chen et al., 2019). Compared with conventional multimedia, AR offers greater interactivity and immersion, enhancing engagement, motivation, knowledge retention, and understanding of abstract concepts (Fitria, 2023; Garrett et al., 2018). Studies have demonstrated AR's effectiveness in increasing motivation and participation among students with special educational needs, improving learning outcomes in physical education, and enhancing usability and learning quality in exercise instruction, highlighting its potential for interactive and student-centered learning (Burns et al., 2022; Calabuig-Moreno et al., 2020; López-Belmonte et al., 2022; Moreno-Guerrero et al., 2020).

AR in Physical, Health, and Nutrition Education

Augmented Reality (AR) has demonstrated strong potential in physical and health education by creating interactive and motivating learning experiences that improve participation, motivation, and learning outcomes through realistic 3D representations and immersive activities

(Calabuig-Moreno et al., 2020; Klochko et al., 2020). AR also enhances understanding of nutrition and healthy habits, supports inclusive education, and can be effectively implemented using the ADDIE model (Henchoz et al., 2019; Kulpy & Bekaroo, 2017; N. A. B. M. Mokmin & Rassy, 2022a; Paramita et al., 2021; Tomczyk & Gottschalk, 2024). However, despite its proven benefits, limited studies have examined adolescents' satisfaction with AR-based learning in physical activity education compared with conventional methods, even though satisfaction influences motivation and long-term behavioral change (Hordiienko et al., 2020; Mittmann et al., 2022; Tomczyk & Gottschalk, 2024).

Method

Research Design

This study employed a quasi-experimental mixed-methods design to evaluate adolescents' satisfaction with learning through an Augmented Reality (AR) application for physical activity promotion. The design enabled comparison between AR-based and traditional PowerPoint instruction and is commonly used in educational technology research where full experimental control is impractical (Fraenkel et al., 2012). Satisfaction was assessed across engagement, motivation, ease of use, and overall experience, consistent with previous AR studies emphasizing satisfaction as an indicator of usability and learning quality (Burns et al., 2022; Moreno-Guerrero et al., 2020). Quantitative data were collected through Likert-scale questionnaires, while qualitative responses provided deeper insights into learners' experiences (Creswell, 2022). The AR application served as the instructional tool rather than the object of evaluation, with the study focusing on satisfaction outcomes rather than application development.

Participants

A total of 60 secondary school students participated in this study and were randomly assigned into an experimental group (AR application, $n = 30$) and a control group (PowerPoint, $n = 30$) to reduce bias and strengthen internal validity (Liang et al., 2023; López-Belmonte et al., 2022). The study was conducted online in an Indonesian secondary school using the Assemblr platform. Demographic data, including age, gender, and educational background, were collected. Adolescents were selected due to their consistently low physical activity levels globally, making them a key target for technology-supported health education interventions (WHO, 2020; Time, 2019).

Instruments

The main instrument in this study was an Augmented Reality (AR)-based learning application developed to promote physical activity among adolescents and used as the experimental learning medium, while PowerPoint served as the control condition. The application was developed using the ADDIE model to align content, learning objectives, and user interaction (Ariffin et al., 2022). A needs analysis showed that 92.3% of students preferred interactive, technology-supported learning materials. The application included interactive 3D models of physical activities with calorie information and features such as tap interaction, zoom, and 360° rotation, developed using Assemblr Studio for smartphone and desktop access. QR markers enabled interaction with AR content, and the application was optimized for Android devices and stable internet use. Expert review and pilot testing confirmed content accuracy, usability, and ease of navigation before implementation.

Satisfaction Questionnaire

Learner satisfaction was measured using a structured questionnaire adapted from previous AR-based educational research (Burns et al., 2022; Moreno-Guerrero et al.,

2020). The instrument consisted of three parts:

- **Section A:** Demographic information (age, gender, and school level).
- **Section B:** 10 items assessing satisfaction on a 5-point Likert scale (1 = strongly disagree to 5 = strongly agree) across four dimensions, which are ease of use, engagement, motivation, and overall satisfaction.
- **Section C:** Open-ended questions allowing participants to express opinions, experiences, and suggestions regarding the AR application.

The questionnaire was validated by two experts to ensure content relevance and clarity. Cronbach's alpha coefficients confirmed internal consistency reliability above 0.80.

This section describes the study instruments, including the AR application as the learning tool and the questionnaire as the measurement instrument for evaluating adolescents' satisfaction with AR-based learning. The questionnaire measured four domains: Ease of Use, Engagement, Motivation, and Overall Satisfaction, using multiple items rated on a five-point Likert scale (1 = strongly disagree to 5 = strongly agree). The complete instrument is presented in Table 1 and provides a comprehensive assessment of usability, motivation, and learning experience.

Procedure

The procedure began with a briefing session in which participants were informed about the study objectives and ethical considerations, including voluntary participation and confidentiality. Participants then received access to the assigned learning media. The AR application, developed using the **ADDIE model** (Analysis, Design, Development, Implementation, and Evaluation), presented physical activity content with 3D visualizations and interactive features. ADDIE has been identified as one of the

most robust frameworks for developing AR-based educational tools because it ensures systematic alignment of learning objectives, content, and user interaction (Apandi et al., 2023; N. A. B. M. Mokmin & Rassy, 2022; N. A. M. Mokmin et al., 2025).

The control group received identical content through PowerPoint slides, a conventional delivery method still widely used in schools. Both groups studied the material within the same timeframe to control for exposure duration. Immediately after the intervention, participants completed the questionnaire. Conducting the entire procedure online ensured convenience, standardization, and accessibility for all participants.

Data Analysis

Quantitative data were analyzed using SPSS software. A normality test indicated that the dataset was not normally distributed; therefore, the Mann–Whitney U test was employed. Non-parametric tests are commonly applied in AR research when data violate normality assumptions, as they provide robust comparisons between independent groups (Moreno-Guerrero et al., 2020). Descriptive statistics, including means, medians, and standard deviations, were also calculated to summarize overall satisfaction scores.

Qualitative data from the open-ended questions were analyzed using thematic analysis. This approach allowed the identification of recurring themes such as usability, motivation, and challenges faced by students. Thematic analysis is often used in AR and educational health research to provide richer interpretations of user experiences (Mittmann et al., 2022; Tomczyk & Gottschalk, 2024).

Table 1. Questionnaire Domains and Items

Domain	Item Code	Item Statement	Scale
Ease of Use	EU1	The AR application was easy to use and navigate.	1–5 Likert
	EU2	The functions and menus of the AR application were clear and understandable.	1–5 Likert
	EU3	I could access and use the AR features without difficulty.	1–5 Likert
Engagement	EN1	The AR activities kept me interested throughout the lesson.	1–5 Likert
	EN2	I felt more involved and focused while learning through the AR application.	1–5 Likert
	EN3	I enjoyed interacting with the 3D AR objects and exploring the content.	1–5 Likert
Motivation	MO1	The AR learning experience encouraged me to learn more about physical activity.	1–5 Likert
	MO2	The AR application increased my motivation to participate in physical activities.	1–5 Likert
Overall Satisfaction	OS1	I am satisfied with learning through the AR application.	1–5 Likert
	OS2	The AR learning experience was better than traditional PowerPoint-based lessons.	1–5 Likert

RESULT AND DISCUSSION

Application Design

The educational media product developed in this study is an Android-based application that employs Augmented Reality (AR) technology to guide users in performing physical activities (Rachsy et al., 2026). The application presents various physical activities using detailed and realistic 3D models as the main objects. The content allows users to interact directly with these objects through features such as “tap to start” and “tap for information.” Users can also zoom in and out or rotate the objects 360 degrees horizontally and vertically, thereby enhancing visualization and engagement.

The AR-based educational media is highly flexible and accessible, as it can be used on both mobile phones and computers via the Assemblr Studio platform. The application is available as a smartphone app and can also be accessed through a web browser, increasing its accessibility for diverse users.

The application's development followed the ADDIE research and development model (analysis, design, development, implementation, and evaluation). Results from the needs analysis revealed that 92.3% of respondents expressed a strong demand for educational media that promotes physical activities through AR applications. This need is largely driven by limited awareness of the health benefits of simple daily physical activities of at least 30 minutes, coupled with the tendency of adolescents to spend more time on their phones than engaging in physical exercise during leisure time.

The instructional content integrated into the AR media includes the definition of physical activity, categories of activities ranging from light to moderate to vigorous intensity, the estimated calories burned for each type, and 3D examples of physical activities. This combination ensures that users not only understand the concept of physical activity but also receive practical guidance for application in daily life.

For implementation, the AR media was run on an Android device with a 6.6-inch HD+ IPS LCD display, 1612 × 720 pixel resolution, and a 90 Hz refresh rate. The Assemblr application was used to embed and present AR content. The design emphasized ease of use by presenting familiar daily activities, including calorie information for each activity type, and incorporating supportive visuals. Learners could use the application independently thanks to these considerations. Notably, similar technology-driven approaches, such as the Empire application for nutrition education, have shown positive effects in increasing physical activity, though not necessarily in improving diet quality among women with overnutrition status (Palupi et al., 2022).

The initial display of the AR physical activity application is shown in Figure 1, which serves as the entry point to all sections. From this interface, users can select “start” to proceed to the main content, which presents comprehensive materials on physical activities.

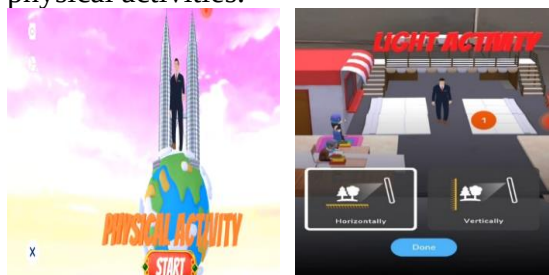


Fig. 1 AR initial display and Display angle selection menu

Figure 2 shows the material on physical activities and examples of light and moderate physical activities. The application displays several examples of light, moderate, and vigorous activities. Users can view, learn, and practice these activities daily.

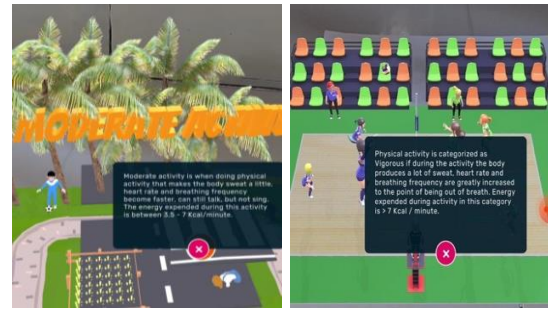


Fig. 2 General display of AR physical activities and examples of light, moderate and vigorous activities

Only the Assemblr Studio application can scan markers such as QR barcodes or custom markers in the form of rendered photos of physical activities, which cannot be accessed through a gadget's regular camera. The performance of the Assemblr Studio application heavily depends on internet speed and the gadget's performance; if the internet is fast and stable and the gadget performs adequately, the application will run smoothly. The use of FCAR media positively impacts children's interest in consuming nutritious food and helps improve nutritional understanding for parents.

User Satisfaction Analysis Socio-demographic characteristics

The average age of respondents was 18.1 years with an age range of 17–19 years. Based on gender, almost half were female (48.3%), while 51.7% were male. Based on the results of the body mass index calculation, the average BMI was $21.07 \pm 2.75 \text{ kg/m}^2$ for the AR group and the average BMI was $20.83 \pm 3.86 \text{ kg/m}^2$, indicating that in general the respondents had normal nutritional status.

The analysis focused on determining adolescents' satisfaction with learning through the Augmented Reality (AR) application compared to traditional PowerPoint-based instruction. The questionnaire responses were categorized into four domains: Ease of Use, Engagement, Motivation, and Overall Satisfaction, as shown in Table 1. For each domain, descriptive statistics were

calculated to obtain mean, median, and standard deviation values, followed by normality testing to assess data distribution. Since the dataset did not meet normality assumptions, the Mann–Whitney U test was used to compare satisfaction scores between the AR and PowerPoint groups. This non-parametric approach provided a reliable analysis of group differences across all satisfaction dimensions, ensuring robustness of results even with non-normally distributed data.

The subsequent sections present the statistical results for each domain, beginning with the overall test of normality and followed by the comparative analysis of satisfaction levels between the two groups.

Table 2. Hypothesis Test Summary

Null Hypothesis	Test	Sig	Decision
The distribution of Score is the same across categories of groups.	Independent-Samples Mann-Whitney U Test	.000	Reject the null hypothesis

Based on the results of the Mann–Whitney U test, there was a statistically significant difference in satisfaction scores between the two groups ($p < 0.05$). Participants who used the Augmented Reality (AR) application reported higher satisfaction across all four domains, Ease of Use, Engagement, Motivation, and Overall Satisfaction compared to those who learned through PowerPoint materials.

Ease of Use:

Students in the AR group consistently rated the application as easy to navigate and intuitive to operate. They indicated that the interface and functions were clearly organized, allowing them to access the content smoothly. This finding aligns with previous research emphasizing the usability advantages of AR environments that integrate interactive elements and real-time feedback (Burns et al., 2022; Moreno-Guerrero et al., 2020).

Engagement:

The AR group also demonstrated greater engagement throughout the learning process. Learners reported that the 3D visualizations and interactive features captured their attention and maintained interest, making the learning experience more enjoyable. These findings correspond with Calabuig-Moreno (2020) and Liang (2023), who found that AR promotes active participation and immersion in physical education contexts (Calabuig-Moreno et al., 2020; Liang et al., 2023).

Motivation:

The use of AR significantly enhanced students' motivation to learn about physical activity. Participants noted that the immersive presentation encouraged them to explore the content further and inspired them to adopt healthier behaviors. This outcome supports earlier studies indicating that AR increases learner motivation by providing meaningful and personalized experiences (Fitria, 2023; Tomczyk & Gottschalk, 2024).

Overall Satisfaction:

Overall, students expressed high satisfaction with the AR learning experience, describing it as more interactive and informative than traditional lessons. They also indicated a preference for continuing to use AR in future health-related topics. (Mittmann et al., 2022; N. A. M. Mokmin et al., 2025).

Collectively, these findings confirm that AR technology enhances adolescents' satisfaction with learning about physical activity by making the process more engaging, motivating, and user-friendly. The integration of immersive visualization with interactive learning supports not only knowledge acquisition but also positive attitudes toward active and healthy lifestyles.

The research hypothesis is H0: There is no significant difference between Group 1 (AR) and Group 2 (PowerPoint) in the mean scores. A non-parametric test was conducted on data that did not follow a normal distribution. Based on the normality test, it was found that Group 1 and Group 2 did not

follow a normal distribution, with the significance values shown in Table 3.

Table 3. Test Of Normality

Test Of Normality				
Kolmogorov-Smirnov ^a				
Score	Group	Statistic	df	Sig.
	Group 1	0.204	30	0.003
	Group 2	0.162	30	0.044

Therefore, the Mann-Whitney U test was conducted to determine whether there is a significant difference in user satisfaction between Group 1 (AR) and Group 2 (PowerPoint). The score distributions were statistically significantly different between Group 1 and Group 2, with $p = 0.000$. The median value of Group 1 was higher (4.45) than that of Group 2 (2.14). Asymptotic significance is displayed. The significance level is 0.050.

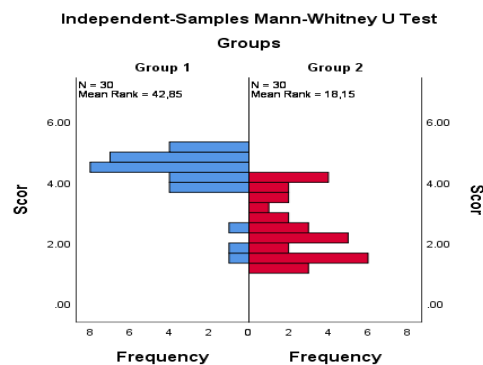


Fig. 3. Distributions of the two groups: Independent-Samples Mann-Whitney U Test.

Figure 3 shows the mean, standard deviation, and median values. Group 1 (AR) outperformed Group 2 (PowerPoint) in both mean and median values. Group 2 had a larger standard deviation compared to Group 1, indicating more variation in scores. Table 4 shows the summary of the Independent Samples Mann Whitney U Test. The Independent Samples Mann Whitney U Test showed a U value of 79.500, a standardized test statistic of $Z = -5.480$, and a significance level of $p < 0.001$. These results indicate a statistically significant difference between the scores of the two groups.

Table 4. Independent-Samples Mann-Whitney U Test Summary

Independent-Samples Mann-Whitney U Test Summary	
Total N	60
Mann-Whitney U	79.500
Wilcoxon W	544.500
Test Statistic	79.500
Standard Error	67.611
Standardized Test Statistic	-5.480
Asymptotic Sig. (2-sided test)	.000

Based on the research results, it can be concluded that the group using AR physical activity had higher satisfaction and experience than the group using PowerPoint. Overall, the findings support that learning using AR results in a better experience and can enhance performance compared to learning with non-reality-based media. This is also supported by Burns who stated that AR development can help faster absorption of information or education, thus creating a better user experience (Burns et al., 2022). Ultimately, the purpose of this study is to determine whether the use of AR can influence the level of public satisfaction and experience with education about physical activity.

Physical activity plays a vital role in accelerating the body's metabolism, including nutrient metabolism, and contributes to balancing nutrient intake and energy expenditure. By regulating this balance, physical activity helps maintain overall physiological stability and supports healthy bodily functions. Previous research has shown that excessive use of electronic devices, particularly mobile phones, is negatively associated with physical activity among adolescents. Specifically, high levels of screen time place adolescents' physical activity within the moderate category, indicating that the longer the duration of device usage, the less time is spent on physical movement (Rahmi et al., 2021). Similarly, studies on adults have identified age as one of the strongest factors influencing physical activity levels, where

increasing age is associated with better health outcomes and a tendency to engage in more intense forms of activity (Adigüzel et al., 2021).

A review of the literature highlights several types of physical activities recommended for adults, categorized by intensity and suggested duration. Light activities include leisurely walking, sitting, or working at a computer. Moderate activities consist of gardening, cycling, or playing ball games, while vigorous activities encompass playing volleyball, running, or engaging in physically demanding work such as construction. These categories serve as practical examples that were incorporated into the development of the Augmented Reality (AR) Physical Activity application to ensure relevance and applicability to users' daily routines.

The AR Physical Activity application was designed to enable users to interact directly with realistic 3D objects, allowing them to view physical activities in an engaging and immersive manner. Such interactivity is intended to increase learner motivation and enhance the overall experience of exploring physical activity content. By transforming physical activity education into an enjoyable and interactive process, the AR application has the potential to improve understanding and encourage users to adopt healthier behaviors.

Discussion

The present study demonstrated that adolescents reported significantly higher satisfaction when using an Augmented Reality (AR) based physical activity application compared to traditional PowerPoint instruction. These findings support growing evidence that immersive and interactive technologies enhance engagement, motivation, and learning quality by making learning experiences more meaningful and visually engaging (Burns et al., 2022; Liang et al., 2023; Moreno-Guerrero et al., 2020). The results

are also consistent with recent studies showing that immersive technologies improve student learning experiences and engagement across educational contexts, including art and design education through Virtual Reality and AI-supported learning environments (J. Chen, Mokmin, & Qi, 2025; J. Chen, Mokmin, & Su, 2025; Su & Mokmin, 2024; Wang, J., Mokmin, N. A. M., & Ji, S.). In particular, the higher scores across the four satisfaction domains, namely ease of use, engagement, motivation, and overall satisfaction, suggest that AR can strengthen user experience and support more effective health-related education.

Ease of Use

The domain of ease of use reflects the perceived usability of the AR application. Students in the AR group found the application intuitive and easy to navigate, consistent with earlier studies emphasizing the importance of simplicity in educational interface design (Garrett et al., 2018). This finding supports the Technology Acceptance Model (TAM), which posits that ease of use is a key determinant of users' acceptance and satisfaction with new technologies (Scherer et al., 2019). When learners can access and manipulate AR content without difficulty, their cognitive resources are freed for meaningful learning rather than interface management. Therefore, the usability of the AR environment plays a vital role in promoting technology adoption in educational settings.

Engagement

The engagement results indicate that AR learning environments can maintain learners' attention and participation more effectively than traditional materials. This finding aligns with constructivist learning theory, which emphasizes active learner involvement through exploration and interaction. AR's ability to integrate real-world context with digital visualization enables students to experience content dynamically, encouraging deeper cognitive and emotional engagement (Calabuig-

Moreno et al., 2020; Liang et al., 2023). This outcome also resonates with Mokmin and Masood (2015), who highlighted that immersive digital tools can foster creative and participatory learning experiences by situating knowledge in interactive contexts (Mokmin N. A. M, & Masood, 2015).

Motivation

The motivation domain demonstrated that AR increased learners' enthusiasm and willingness to learn about physical activity. The results support the ARCS motivational model (Attention, Relevance, Confidence, and Satisfaction), which suggests that attention and relevance are essential for sustaining learner motivation (Fitria, 2023). AR's visual interactivity captures learners' attention, while its contextual relevance, linking physical activity concepts to real-life behaviors, enhances their intrinsic motivation. Prior studies have shown similar effects, where AR stimulated curiosity and persistence in learning tasks (Tomczyk & Gottschalk, 2024). Consequently, AR's motivational impact extends beyond enjoyment, influencing students' long-term attitudes toward health and physical fitness.

Overall Satisfaction

Overall satisfaction integrates learners' general perceptions of usability, engagement, and motivation. The positive responses in this domain indicate that adolescents valued the AR learning experience more than the traditional format. They perceived it as enjoyable, practical, and informative, suggesting that AR not only improves comprehension but also emotional satisfaction with learning. These results align with prior AR studies showing that satisfaction predicts sustained usage and higher learning outcomes (Mittmann et al., 2022; N. A. B. M. Mokmin & Rassy, 2022). From a pedagogical perspective, satisfaction represents a critical factor for encouraging continuous learning and technology integration in physical education.

Practical Implications

Practically, this study underscores the potential of AR applications to enhance the delivery of health education by transforming passive lessons into interactive learning experiences. Educators can integrate AR-based content to visualize movement techniques, monitor student participation, and create immersive learning scenarios that encourage active lifestyles. This approach also aligns with Malaysia's broader educational technology initiatives that promote digital learning and health awareness among youth.

Moreover, the study provides empirical evidence supporting the use of AR to increase learner satisfaction an essential determinant of both engagement and learning effectiveness. Schools and instructional designers can adapt similar AR frameworks using accessible platforms such as Assemblr Studio to enrich teaching materials in physical and health education.

Limitations and Future Directions

The sample size was relatively small and restricted to one educational context, which may limit generalizability. Future studies should involve larger and more diverse populations and examine whether increased satisfaction with AR learning leads to sustained physical activity and improved health literacy. In addition, integrating AR with emerging technologies such as Virtual Reality (VR), Artificial Intelligence (AI), and adaptive learning systems may further personalize learning experiences and enhance health education outcomes through tailored content and interactive instructional approaches (J. Chen, Mokmin, & Qi, 2025; N. A. M. Mokmin & Masood, 2015; Wang, J., Mokmin, N. A. M., & Ji, S., 2024). Overall, this study adds to growing evidence that immersive and intelligent educational technologies can transform learning experiences.

Interpretation of Key Findings

The statistically significant difference in satisfaction highlights the ability of AR to foster active participation in learning. Students in the AR group consistently described the tool as enjoyable and motivating, noting that interactive 3D models improved their understanding of physical activities. Similar benefits have been observed in prior AR and VR research, where immersive features supported learner motivation and skill acquisition (Calabuig-Moreno et al., 2020; Liang et al., 2023; Mokmin & Ridzuan, 2022).

These findings also resonate with broader trends in educational technology. For instance, Mokmin and Masood (2015) highlighted through their development of a case-based reasoning system (CBR-PROMATH) that intelligent digital tools can personalize and support learning by adapting to learners' needs. Likewise, Wang, J., Mokmin, N. A. M., & Ji, S. (2024) reviewed virtual reality (VR) in art and design courses and found that immersive technologies improve student experiences by fostering creativity, engagement, and higher-order thinking. Both examples underscore how AR, like VR, can play a transformative role in education by offering learner-centered environments that go beyond traditional instruction.

Qualitative responses in this study further reinforced these outcomes, with AR participants describing their experience as *fun* and *easy to understand*, while PowerPoint users reported disengagement. These observations echo findings from VR laboratory environments in science education, where virtual interactions enhanced presence and immersion, ultimately leading to more profound engagement with content (Apandi et al., 2023). Together, these results suggest that immersive learning environments, whether AR or VR, create conditions for active learning, which may help address the challenge of declining adolescent physical activity levels worldwide (WHO, 2020).

Theoretical and Practical Implications

Theoretically, the findings support constructivist and experiential learning approaches, where learners actively interact with content rather than passively consume it. By enabling students to rotate, zoom, and simulate physical activities, AR fosters hands-on learning consistent with experiential education models (Garrett et al., 2018). These results also extend earlier AR research in physical education by demonstrating that user satisfaction is not only a byproduct but also a key driver of engagement and sustained motivation (N. A. B. M. Mokmin & Rassy, 2022). Practically, the study illustrates the potential of AR as a complementary tool in physical education curricula. By making lessons more engaging and visually rich, AR can encourage adolescents to develop healthier behaviors. Moreover, the broader integration of AR with other immersive tools, such as VR science laboratories (Apandi et al., 2023), shows promise for cross-disciplinary applications in schools. This positions AR as part of a larger ecosystem of immersive technologies capable of supporting not only physical education but also science, mathematics, and design learning (Mokmin & Masood, 2015; Wang, J., Mokmin, N. A. M., & Ji, S., 2024).

Limitations

While the findings are promising, this study has several limitations. The relatively small sample size ($n = 60$) and single-institution setting limit the generalizability of the results. Future studies should involve larger and more diverse samples across multiple contexts. Furthermore, the study focused on satisfaction alone, which, while important, does not measure behavioral change or actual improvements in physical activity levels. Longitudinal studies are required to examine whether AR adoption leads to sustained health benefits. Finally, contextual factors such as access to devices, internet stability, and teachers' readiness to

integrate AR may have influenced results, as highlighted in other AR implementation studies (Mokmin et al., 2025).

Future Research

While the findings are promising, this study has several limitations. The relatively small sample size ($n = 60$) and single-institution setting limit the generalizability of the results. Future studies should involve larger and more diverse samples across multiple contexts. Furthermore, the study focused solely on satisfaction, which, while important, does not measure behavioral change or actual improvements in physical activity levels. Longitudinal research is required to examine whether satisfaction with AR learning leads to sustained engagement in physical activities and improved health outcomes.

Contextual factors such as access to devices, internet stability, and teachers' readiness to integrate AR may have also influenced results, as highlighted in other AR implementation studies (Mokmin et al., 2025). Future research should therefore explore how teacher training, infrastructure, and digital literacy impact the success of AR adoption in schools.

Beyond the immediate findings, future studies may consider integrating AR with other immersive and intelligent technologies, such as Virtual Reality (VR) or Artificial Intelligence (AI), to enhance personalization and creative engagement in health education. Wang, J., Mokmin, N. A. M., & Ji, S., (2024) demonstrated that immersive VR technologies can improve student engagement and creative learning experiences in art and design education, while *Su and Mokmin (2024)* showed that AI-supported learning environments enhance sustainability and accessibility in visual art education. Drawing from these insights, future AR-based health studies could combine immersive design with intelligent learning systems to strengthen engagement, interactivity, and long-term motivation among adolescents.

Overall, this study contributes to growing evidence that AR can play a transformative role in education. By improving satisfaction, engagement, and motivation, AR technologies support both cognitive and behavioral dimensions of learning, offering a powerful tool for promoting physical activity and healthy lifestyles among adolescents.

Conclusion

This study evaluated adolescents' satisfaction with learning through an Augmented Reality (AR) application for physical activity promotion. Findings showed that students using AR reported significantly higher satisfaction than those using conventional PowerPoint instruction, particularly in engagement, motivation, ease of use, and overall learning experience. These results support previous studies showing that AR enhances health-related learning through interactive 3D visualization, increasing presence, enjoyment, and motivation (Burns et al., 2022; Liang et al., 2023; Moreno-Guerrero et al., 2020).

The findings highlight the pedagogical value of AR in making physical education more interactive and meaningful while emphasizing satisfaction as an important factor influencing continued use and learning effectiveness. However, the study was limited by its sample size and duration. Future research should include larger populations, longitudinal designs, and investigate whether AR satisfaction leads to actual behavioral changes and improved health literacy. Combining AR with technologies such as AI and VR may further personalize and sustain learning experiences (Wang, J., Mokmin, N. A. M., & Ji, S., 2024). Overall, AR offers a promising learner-centered approach for promoting active and healthy lifestyles among adolescents.

Disclosure Statement

- **Ethics Approval and Consent to Participate:** This study has been cleared

by the ethics committee and informed consent to participate in this study was obtained from all participants Number: 1580/KEPK/FKUMSU/2025

- **Availability of Data and Materials:** The datasets generated and analyzed during the current study are not publicly available due to restrictions specific to this study but are available from the corresponding author upon reasonable request.
- **Authors' Contributions:** [Emilia, E] conceptualized and designed the study and conducted the research; [Hanifa, Z. N. and Rachsy, G. N.] conducted the intervention and collected the data; [Rosmiati and Rachsy, G. N.] contributed to data interpretation and data analysis; [Mokmin, N.A.M] prepared the initial manuscript draft; and all authors critically revised the manuscript and approved the final version for publication.
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