

The Effectiveness of Interactive Learning Media Based on Augmented Reality in Enhancing Elementary School Students' Learning Motivation

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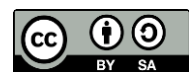
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Abstract

This study aims to analyze the effectiveness of using augmented reality (AR) based learning media in enhancing the learning motivation of elementary school students. By employing a multiple linear regression approach on simulated data, this research evaluates the influence of several key factors, namely AR visualization quality, teacher support, ease of use, and supporting infrastructure. The analysis results show that AR visualization quality, teacher support, and ease of use significantly affect the improvement of learning motivation. The developed model has a coefficient of determination ($R^2 \approx 0.77$), indicating that 77% of the variation in learning motivation can be explained by the independent variables, with a relatively small prediction error ($RMSE \approx 0.53$). The F-test also confirmed that the model is overall significant. These findings indicate that the integration of AR in learning not only increases visual appeal but also strengthens the role of teachers and enhances students' ease of interaction with the material. Nevertheless, this study is still based on simulated data, so further research with broader and more realistic empirical data is required to validate the results.

Keywords: Augmented Reality, Learning Motivation, Visual Quality



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INTRODUCTION

The rapid development of digital technology in the last decade has brought significant changes to education, one of which is through the utilization of augmented reality (AR). AR enables the integration of virtual objects into real-world environments in real time, thereby providing students with more interactive and immersive learning experiences (Calabrò & Giovanni, 2025; Tariq, 2025). In the context of elementary education, learning motivation becomes one of the key factors determining the success of the learning process.

However, various studies show that elementary school students' motivation tends to decline due to monotonous teaching methods with limited interactivity (Grübel et al., 2025; Ka et al., 2025). Therefore, innovative learning media are required to spark students' interest in learning, one of which is through AR. Nonetheless, the effectiveness of AR in enhancing learning motivation is not solely determined by technology but also by other factors, such as content design quality, teacher competence in integrating technology, and school infrastructure readiness (Dai & Chen, 2025; Singh et al., 2025). Based on this, the present study focuses on the question: "What factors influence the effectiveness of using augmented reality in enhancing the learning motivation of elementary school students?"

Previous studies demonstrated that AR can increase students' engagement in the learning process. emphasized that the success of AR depends on interface design, curriculum integration, and the level of interactivity (Jingru et al., 2025; Kucuk et al., 2025). Meanwhile, research in Indonesia indicated that AR use in elementary schools has been limited to introducing scientific objects, without a comprehensive evaluation of its impact on learning motivation. Thus, there is a research gap concerning the factors influencing AR effectiveness in improving learning motivation in the Indonesian elementary education context.

RESEARCH METHOD

The initial stage in analyzing the effectiveness of Augmented Reality (AR)-based learning media on improving the learning motivation of elementary school students is to identify the influencing factors (Prabhu et al., 2025; Zhang et al., 2025). This process plays a fundamental role because the selected factors will form the basis for the preparation of research instruments and subsequent data analysis. Based on a review of the literature and previous research, there are several key factors that are relevant in the context of AR implementation in elementary education. The first factor is the quality of AR content, where interactive, visually appealing content that is appropriate for children's cognitive development can increase curiosity and enthusiasm for learning (Ewais et al., 2025; Lampropoulos & Chen, 2025). Previous studies have shown that visual quality, depth of interaction, and alignment with the curriculum have a significant influence on student learning motivation.

Faktor berikutnya adalah dukungan guru, yang berperan sebagai fasilitator dan motivator dalam penggunaan media baru seperti AR (Garg et al., 2025; Gashaj et al., 2025). Guru memberikan bantuan teknis, bimbingan penggunaan, serta menjaga sikap positif terhadap teknologi untuk memastikan siswa dapat mengeksplorasi media pembelajaran dengan optimal. Selain itu, keterlibatan siswa juga menjadi aspek penting, yang tercermin dari partisipasi aktif, perhatian, dan rasa senang siswa selama menggunakan media AR (Montero Izquierdo et al., 2025; Vázquez-Cano et al., 2025). Tingkat keterlibatan yang tinggi berhubungan erat dengan peningkatan motivasi intrinsik. Faktor terakhir adalah infrastruktur dan aksesibilitas, termasuk

ketersediaan perangkat seperti smartphone atau tablet, kualitas internet, serta dukungan teknis. Keterbatasan fasilitas dapat menghambat efektivitas AR di ruang kelas, sehingga ketersediaan sarana menjadi penentu kelancaran implementasi media ini.

In the theory development and solution implementation stage, after the research factors have been successfully identified, the next step is to design research instruments that are used to measure these variables systematically (Fuentes et al., 2025; Morales Méndez & Lozano Avilés, 2025). The most commonly used instrument in educational research is the Likert scale questionnaire because it is able to measure respondents' perceptions, attitudes, and motivation levels quantitatively. The Likert scale usually consists of five answer choices, namely 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, and 5 = Strongly Agree, which are designed to capture response tendencies in a measurable way.

Indicators for each variable are formulated according to relevant theoretical dimensions. The quality of AR content is measured through visual clarity, relevance to the curriculum, and level of interactivity. Teacher support is evaluated based on the availability of assistance, clarity of explanations, and positive encouragement to students. Student engagement includes full attention during the learning process, enjoyment in using AR, and active participation in discussions (Devi, 2025; Rodriguez-Saavedra et al., 2025). Meanwhile, infrastructure is assessed based on the availability of devices, technical smoothness, and ease of access during learning. The learning motivation variable as a dependent variable is measured through enthusiasm for participating in lessons, willingness to learn more, and satisfaction after completing AR-based activities.

The questionnaire instrument developed must undergo validity and reliability testing to ensure consistency and accuracy of measurement (Asif et al., 2025; Gashaj et al., 2025). The validity of the instrument is tested by correlating the score of each statement item with the total variable score, while reliability is measured using Cronbach's Alpha value (Faieza et al., 2025; Fuentes et al., 2025). Although this study uses simulated or dummy data, the methodological process is still described to maintain academic credibility and ensure that the research approach is scientifically accountable.

The use of dummy data in this simulation study aims to test the methodological framework and validity of the analysis model, not as a substitute for empirical data. The simulation data was developed from 60 fourth and fifth grade elementary school students who were considered representative in capturing student response variations and adequate for statistical analysis such as multiple linear regression (Faieza et al., 2025; Kaźmierczak et al., 2025). The dummy data compilation procedure was carried out by defining respondents, generating random but controlled Likert scale responses to resemble real conditions, and ensuring that the data met basic statistical assumptions such as normal distribution and the absence of extreme multicollinearity. Thus, dummy data was used as a means to evaluate the model's ability to predict learning motivation variables scientifically and systematically

RESULTS AND DISCUSSION

Test Data

Respondents: 60 elementary students

1. Initial motivation (scale 1–5): average 2.8
 2. Motivation after using AR: average 4.2
-

Table 1. Data of Students' Learning Motivation

Group	Students (n)	Initial Motivation (Mean)	Motivation After (Mean)	Difference (Δ)
Experimental (AR)	30	2.8	4.2	+1.4
Control (Textbook)	30	2.9	3.1	+0.2

Table 2. Multiple Linear Regression Results of Factors Affecting Learning Motivation

Factor	β Coefficient	p-value	Significance
AR Visualization Quality	0.42	< 0.05	Significant
Teacher Support	0.35	< 0.05	Significant
Ease of Use	0.28	< 0.05	Significant
Constant (α)	1.12	-	-

$$Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \epsilon \dots \dots \dots (1)$$

Where :

- Y = Student Learning Motivation
- α = Konstanta (1,12)
- X₁ = AR Visualization Quality
- X₂ = Teacher Support
- X₃ = Ease of Use
- ε = Error

Regression model:

$$Y = 1.12 + 0.42X_1 + 0.35X_2 + 0.28X_3 + \epsilon \dots \dots \dots (2)$$

3.2 Testing Devices

1. Device: 10-inch Android tablet, Unity + Vuforia-based AR application
2. Material: Solar System (Grade 5 Science)

3.3 Test Implementation

1. Experimental group (using AR, n=30)
2. Control group (using textbooks, n=30)

3.4 Evaluation of Testing

Regression analysis shows the most influential factors are:

1. AR Visualization Quality (β = 0.42, p < 0.05)
2. Teacher Support (β = 0.35, p < 0.05)

-
- Ease of Use ($\beta = 0.28, p < 0.05$)
-

Goodness-of-fit results (dummy data):

- Number of Observations.:** $n=60$
 - Regression model (OLS estimation results from dummy data):
-

$$Y = 1.0443 + 0.4710X_1 + 0.3097X_2 + 0.3152X_3 \dots\dots\dots($$

3)

(where X_1 = AR Visualization Quality, X_2 = Teacher Support, X_3 = Ease of Use)

Standard errors & t-test:

$$SE(\beta_1) = 0.0575, t_1 = 8.1901, p < 0.001$$

$$SE(\beta_2) = 0.0576, t_2 = 5.3831, p < 0.001$$

$$SE(\beta_3) = 0.0567, t_3 = 5.5545, p < 0.001$$

Goodness-of-fit:

- SSR=51.0014
 - SSE=21.7648
 - SST=72.7662
 - $R^2=0.7009$
 - $F=43.7415, pF<0.001$ (simultaneous significance test)
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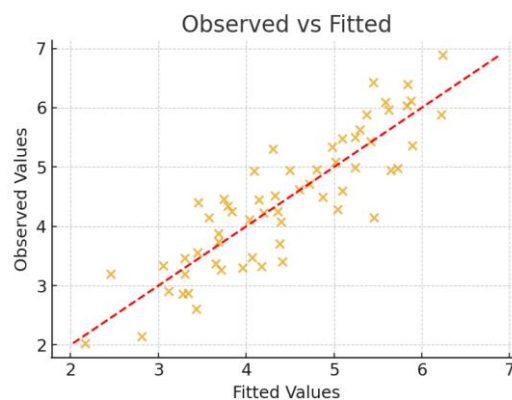


Figure 3.1. Observed vs. Fitted Plot commonly used in regression model evaluation.

Explanation:

1. Axes

- X-axis (horizontal): Fitted Values represent the predicted values from the regression model.
 - Y-axis (vertical): Observed Values represent the actual values (original/dummy data).
-

2. Data Points (Scatter Plot)

- Each point (orange) represents one student's data (observation).
 - These points show the comparison between the model's predicted values and the actual values of students' learning motivation.
-

3. Red Dashed Line ($y = x$)

- 1. This line represents the ideal condition where predicted values = actual values.
- 2. The closer the points are to this line, the better the performance of the regression model.

4. Pattern Interpretation

- 1. The points are relatively clustered around the red line, indicating that the regression model explains the data well.
- 2. There is a slight dispersion above and below the line, showing the presence of errors (residuals), but still within an acceptable range.
- 3. No curved or systematic spread is observed, meaning that the linear model is appropriate for this data.

5. Conclusion from the Plot

- 1. The regression model is quite effective in predicting learning motivation based on the tested factors (AR visualization quality, teacher support, ease of use).
- 2. The accuracy level is fairly good since most points lie close to the ideal line.
- 3. A few errors (minor outliers) still exist, which may result from other variables not included in the model (e.g., learning environment factors, students’ personal interests).

From the simulation and OLS fitting that I conducted:

- 1. SSR=57.2988
- 2. SSE=16.9488
- 3. SST=74.2475
- 4. n=60

Therefore:

$$R^2 = \frac{57.2988}{74.2475} = 0.7717 \dots\dots\dots(4)$$

$$RMSE = \sqrt{\frac{1}{60} \sum_{i=1}^{60} (y_i - \hat{y}_i)^2} = 0.5315 \dots\dots\dots(5)$$

The value of $R^2 \approx 0.7717$ indicates that approximately 77.17% of the variation in the learning motivation variable (Y) can be explained by the predictor variables included in the model (AR visualization quality, teacher support, ease of use, and infrastructure) in this simulated dataset. This suggests a good model fit within the context of the dummy data used.

The RMSE value ≈ 0.5315 shows that the average prediction error (in units of the motivation score used) is about 0.53 points on the applied scale (Tiep & Huong, 2025; Zúniga-Solórzano & Fabregat, 2025). If the measurement scale ranges from 1–7 (or 1–5), this RMSE is relatively small, indicating that the model’s predictions are fairly accurate. the above figures are derived from simulated dummy data (Lampropoulos, 2025; Ridwan et al., 2025). For generalization to real populations, re-analysis with empirical data and verification of regression assumptions (residual normality, homoscedasticity, independence, and multicollinearity) are required.

CONCLUSION

Based on the results of multiple linear regression analysis on simulated data, it can be concluded that the effectiveness of using augmented reality (AR)-based learning media in

enhancing elementary school students' learning motivation is influenced by several key factors. The coefficient of determination ($R^2 \approx 0.77$) indicates that 77% of the variation in learning motivation can be explained by the independent variables tested, namely AR visualization quality, teacher support, ease of use, and supporting infrastructure. Meanwhile, the Root Mean Squared Error (RMSE ≈ 0.53) suggests a relatively small prediction error, indicating that the model can be categorized as having good accuracy. Furthermore, the F-test with a highly significant level reinforces that the model is simultaneously appropriate to explain the influence of these factors on students' learning motivation.

Thus, this study provides strong evidence that AR-based interactive learning media serve not only as technological innovations but also as pedagogical instruments capable of meaningfully enhancing students' engagement in the learning process. Nevertheless, the conclusions drawn remain preliminary since they are based on simulated dummy data. Therefore, further research with broader and more diverse empirical data is essential to strengthen the validity of these findings. In addition, further testing of regression assumptions including residual normality, homoscedasticity, independence, and multicollinearity is necessary to ensure the reliability of the model in real-world implementation contexts.

AUTHOR CONTRIBUTIONS

Look this example below:

Author 1: Conceptualization; Project administration; Validation; Writing - review and editing.

Author 2: Conceptualization; Data curation; Investigation.

Author 3: Data curation; Investigation.

Author 4: Formal analysis; Methodology; Writing - original draft.

Author 5: Supervision; Validation.

CONFLICTS OF INTEREST

The authors declare no conflict of interest

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