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Integrating Augmented Reality, Artificial Intelligence, and Graphic Design to Enhance Learning Quality in Higher Education

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ABSTRACT

This study developed and evaluated interactive learning media integrating augmented reality (AR), artificial intelligence (AI), and graphic design principles for higher education. Using a Design-Based Research approach, the media were iteratively designed, implemented, and refined with undergraduate graphic design students at Universitas Sains Indonesia. Learning effectiveness was assessed through pre- and post-tests, engagement measures, user-experience evaluation, observations, and interviews. Results showed significant improvement in learning outcomes, with a moderate normalised gain (N-Gain = 0.60), a large effect size (Cohen's d = 0.85), and a significant difference between pre- and post-test scores ($p < 0.001$). Students also reported high engagement and positive user experience. Qualitative findings indicated that AR supported immersive conceptual visualisation, while AI enabled adaptive feedback and personalised learning. The findings suggest that combining AR, AI, and graphic design can create an interactive, adaptive, and visually effective learning environment that enhances learning outcomes and student engagement.

INTRODUCTION

The rapid advancement of digital technology in the era of Society 5.0 has fundamentally transformed higher education, particularly in terms of learning approaches, the role of technology, and student characteristics. Education is no longer oriented toward linear knowledge transmission but has shifted toward creating adaptive, collaborative, and technology-enhanced learning experiences. This transformation necessitates the development of innovative learning media capable of accommodating the needs of digital-native students who are accustomed to visual, multimodal, and interactive environments (Singh, 2024; Radianti et al., 2020; Bower et al., 2020). In this context, the integration of Augmented Reality (AR) and Artificial Intelligence (AI) has emerged as a strategic approach to improving the quality of learning in higher education (Zawacki-Richter et al., 2021; Chen et al., 2022).

AR technology enables the integration of virtual objects into real-world environments in real time, creating contextual and immersive learning experiences. In educational settings, AR has been widely utilised to visualise abstract concepts, enhance student engagement, and improve conceptual understanding through direct interaction (Christou, 2026; Ibáñez & Delgado-Kloos, 2020; Akçayır & Akçayır, 2021). Within graphic design education, visualisation is a core competency that extends beyond aesthetics to include the effective communication of ideas through visual media. Therefore, the application of AR in graphic design learning has significant potential to support students in understanding design principles in a more concrete and practical manner.

A growing body of research indicates that AR-based learning can significantly improve student engagement, motivation, and learning outcomes. By enabling interaction with three-dimensional visual objects, AR fosters an exploratory learning environment that goes beyond conventional two-dimensional media (Singh, 2024; Makransky & Petersen, 2021). Furthermore, AR supports experiential learning approaches, which emphasise learning through direct experience

and have been proven effective in enhancing both conceptual understanding and practical skills (Christou, 2026; Radianti et al., 2020).

On the other hand, AI introduces a new paradigm in education through its ability to analyse learning data and provide adaptive responses tailored to individual learners. AI-driven systems can personalise content delivery, adjust learning difficulty levels, and provide real-time feedback based on students' performance and learning behaviour. This leads to more efficient and personalised learning experiences while promoting self-regulated learning (Gill, 2024; Zawacki-Richter et al., 2021). Additionally, AI contributes to the development of critical thinking and adaptive skills, which are essential in navigating the complexity of digital information environments (Hwang & Tu, 2021; Chen et al., 2022).

The integration of AR and AI within learning media creates an ecosystem that is not only interactive but also intelligent and responsive. The combination of these technologies enables the development of learning environments that adapt to user needs while delivering rich visual experiences. Recent studies have demonstrated that the integration of AR and AI can significantly enhance learning quality, particularly in visual- and practice-based learning contexts (Nurlina et al., 2025; Shadiev & Yang, 2020). This is highly relevant to graphic design education, which requires a balance between theoretical understanding, visual exploration, and technical skills.

Despite these advantages, the implementation of AR and AI in education still faces several challenges. One of the primary issues is the lack of integration between technological development and appropriate pedagogical frameworks. Many studies focus heavily on technological innovation without adequately addressing how these technologies can be effectively integrated into instructional design (Zawacki-Richter et al., 2021). Moreover, the role of graphic design principles is often overlooked in the development of technology-based learning media, even though visual communication plays a critical role in determining the effectiveness of information delivery (Norman, 2021; Kurniawan & Naradika, 2026).

Furthermore, previous studies have highlighted that the success of technology-enhanced learning is not solely dependent on technological sophistication but also on the quality of instructional design and user experience (Gill, 2024; Hassenzahl & Tractinsky, 2020). This indicates the need for a multidisciplinary approach that integrates technology, pedagogy, and graphic design in a comprehensive manner, where aesthetic and functional aspects of visual communication play a crucial role in enhancing user engagement and learning effectiveness (Kurniawan & Naradika, 2026).

A significant research gap can be identified in the limited number of studies that integrate AR and AI simultaneously within a graphic design-based learning framework. Most existing research tends to examine AR and AI separately and focuses primarily on technological aspects rather than visual communication and design quality (Akçayır & Akçayır, 2021; Chen et al., 2022). In addition, research specifically addressing the development of AR- and AI-based learning media in the context of higher education graphic design programs remains scarce.

Beyond this gap, there is also a growing demand for learning approaches that are more aligned with the needs of the creative industry. The graphic design industry today requires not only technical proficiency but also creativity, problem-solving skills, and an understanding of user experience (Norman, 2021). Therefore, learning media must be designed to reflect these demands through the integration of advanced technologies and effective visual design principles.

In the context of Universitas Sains Indonesia, particularly in the graphic design study program, the need for innovative learning media is increasingly urgent in response to the evolving demands of the creative industry. Current learning practices that are still dominated by conventional approaches may limit students' creativity and experiential learning opportunities. Therefore, it is essential to develop innovative learning media that can significantly enhance the quality of learning.

Based on the above considerations, this study proposes an innovative approach through the development of interactive learning media based on AR and AI integrated with graphic design principles. The novelty of this research lies in the

integration of three key components—AR technology, artificial intelligence, and graphic design—into a comprehensive learning system. This approach is expected to produce learning media that are not only interactive and adaptive but also visually effective and capable of enhancing students' learning experiences.

Accordingly, the objective of this study is to develop interactive learning media based on Augmented Reality and Artificial Intelligence through the integration of graphic design to improve the learning quality of graphic design students at Universitas Sains Indonesia. This research is expected to contribute theoretically to the development of technology-enhanced learning models and practically to improving the effectiveness of higher education learning, particularly in the field of graphic design.

METHODS

Research Design

This study employed a Design-Based Research (DBR) approach to develop and evaluate interactive learning media integrating Augmented Reality (AR), Artificial Intelligence (AI), and graphic design principles. DBR was selected due to its suitability for developing educational innovations through iterative cycles in real-world contexts.

The research followed four iterative phases: (1) problem analysis, (2) design and development, (3) implementation, and (4) evaluation and refinement. These phases were conducted cyclically to ensure continuous improvement of the developed learning media.

Research Setting and Participants

The study was conducted at Universitas Sains Indonesia, within the Graphic Design Study Program. Participants were selected using purposive sampling and included:

1. 30–50 undergraduate students
2. 2–3 lecturers as subject matter experts
3. 2 media/design experts for validation

All participants had prior experience with digital learning environments.

Development Procedure

The development process followed the DBR iterative model:

1. Problem Analysis
   Identification of learning issues through observation, interviews, and document analysis. The results indicated limited interactivity, lack of immersive visualisation, and absence of personalised learning features.
2. Design and Development
   The learning media was designed by integrating:
   a. AR for 3D visualisation
   b. AI for adaptive feedback and personalisation
   c. Graphic design principles (layout, typography, colour, visual hierarchy, UX)
3. Implementation
   The system was implemented in classroom settings over 4–6 weeks. Students engaged in AR-based visualisation activities, interactive exercises, and AI-supported feedback sessions.
4. Evaluation and Refinement
   Iterative evaluation was conducted based on user feedback, learning outcomes, and expert validation to refine the system.

Variables and Operational Indicators

1. Learning Quality
   Measured through:
   a. Conceptual understanding (pre-post test)

b. Practical design skills (rubric-based assessment)
c. Knowledge retention (delayed test)
d. Transfer ability (project-based task)

2. Student Engagement
Measured across three dimensions:
a. Behavioural (participation, interaction)
b. Emotional (interest, motivation)
c. Cognitive (effort, critical thinking)

3. User Experience (UX)
Measured through:
a. Usability
b. Visual design quality
c. Interaction responsiveness
d. User satisfaction

Data Collection Techniques

Data were collected using a mixed-method approach:

a. Pre-test and post-test to measure learning improvement
b. Questionnaires (Likert scale 1–5) to assess engagement and UX
c. Observations to analyse student interaction
d. Interviews to obtain in-depth qualitative insights
e. Expert validation for content and media quality

Research Instruments

The instruments used in this study included:

a. Learning outcome tests
b. Engagement questionnaire
c. User experience (UX) questionnaire
d. Media validation checklist
e. Interview guidelines

All instruments were tested for validity and reliability prior to use.

Data Analysis

1. Learning Improvement (N-Gain)

$$g = \frac{Posttest - Pretest}{Max - Pretest}$$

Used to measure the effectiveness of learning improvement:

a. $g > 0.7$ (high)
b. $0.3 < g \leq 0.7$ (moderate)
c. $g \leq 0.3$ (low)

2. Statistical Significance (Paired Sample t-test)

$$t = \frac{\bar{X}_d}{S_d/\sqrt{n}}$$

Used to determine significant differences between pre-test and post-test results ($p < 0.05$).

3. Effect Size (Cohen's d)

$$d = \frac{M_2 - M_1}{SD_{pooled}}$$

Used to measure the magnitude of the treatment effect:

a. 0.2 (small)
b. 0.5 (medium)
c. ≥0.8 (large)

4. Reliability Test (Cronbach's Alpha)

$$\alpha = \frac{k}{k-1}\left(1 - \frac{\sum \sigma_i^2}{\sigma_t^2}\right)$$

Used to ensure instrument reliability:

a. $\alpha \geq 0.7$ (acceptable)
b. $\alpha \geq 0.8$ (good)

5. Qualitative Analysis

Qualitative data from interviews and observations were analysed using thematic analysis, including coding, categorisation, and triangulation to ensure validity.

Validity and Reliability

To ensure rigour:

a. Content validity through expert review
b. Construct validity aligned with research variables
c. Reliability tested using Cronbach's Alpha
d. Data triangulation across methods

Ethical Considerations

a. Informed consent obtained from all participants
b. Participation was voluntary
c. Data confidentiality and anonymity were ensured

Research Flow

The research followed an iterative cycle:

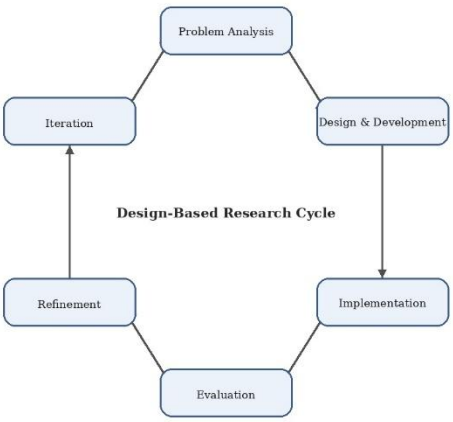

Chart 1. Design-Based Research (DBR) Cycle

RESULTS AND DISCUSSION

The results of this study demonstrate that the integration of Augmented Reality (AR), Artificial Intelligence (AI), and graphic design principles significantly enhances learning quality, student engagement, and user experience in graphic design education. The findings are presented through a combination of quantitative analysis, qualitative insights, and theoretical interpretation to provide a comprehensive understanding of the effectiveness of the proposed learning media.

Learning Outcome Improvement

The effectiveness of the developed learning media was evaluated through pre-test and post-test assessments. The results are presented in Table 1.

Variable	Pre-test Mean	Post-test Mean	N-Gain
Learning Outcome	63.2	85.5	0.60

Table 1. Learning Outcome Improvement

The normalised gain score was calculated using:

$$g = \frac{Posttest - Pretest}{Max - Pretest}$$

The N-Gain value of 0.60 falls within the moderate category, indicating that the AR–AI-based learning media is effective in improving students' understanding and practical skills.

To verify statistical significance, a paired sample t-test was conducted:

$$t = \frac{\bar{X}_d}{S_d/\sqrt{n}}$$

The results showed $p < 0.001$, confirming a statistically significant difference between pre-test and post-test scores. Furthermore, the effect size was calculated:

$$d = \frac{M_2 - M_1}{SD_{pooled}}$$

The obtained value of Cohen's $d = 0.85$ indicates a large effect size, suggesting that the intervention has a strong practical impact. The combination of moderate N-Gain and large effect size indicates that the learning media is both statistically significant and educationally meaningful.

These findings suggest that AR enhances conceptual visualisation, while AI contributes to adaptive learning, resulting in improved student performance.

Student Engagement

Student engagement was measured across behavioural, emotional, and cognitive dimensions. The results are summarised in Table 2.

Dimension	Mean	Category
Behavioral	4.32	High
Emotional	4.45	Very High
Cognitive	4.28	High
Overall	4.35	High

Table 2. Student Engagement Results

The results indicate a high level of engagement, with emotional engagement showing the highest score. This suggests that the immersive and interactive nature of AR significantly increases students' interest and motivation. Behavioural

engagement reflects active participation, while cognitive engagement indicates deeper involvement in learning processes.

User Experience (UX)
User experience was evaluated to assess usability, visual design, interaction, and satisfaction. The results are shown in Table 3.

Dimension	Mean	Category
Usability	4.30	High
Visual Design	4.52	Very High
Interaction	4.34	High
Satisfaction	4.47	Very High
Overall	4.41	High

Table 3. User Experience Results

The highest score was observed in the visual design dimension, highlighting the importance of integrating graphic design principles in learning media development. High usability and interaction scores indicate that the system is user-friendly and responsive, while high satisfaction reflects positive user perception.

Qualitative Findings
Qualitative data from interviews and observations support the quantitative findings. Students reported that AR-based visualisation helped them better understand abstract design concepts through three-dimensional representation. AI-based feedback was perceived as useful for improving design skills and guiding learning progress.

Additionally, students expressed increased motivation and reduced boredom, with many preferring this approach over conventional learning methods. These findings confirm that the integration of AR and AI creates a more engaging and effective learning environment.

Comparative Analysis
From a comparative perspective, the proposed AR–AI learning model demonstrates superior performance compared to conventional and single-technology approaches.

Conventional learning methods, which rely on static materials and one-way instruction, typically result in moderate learning outcomes and lower engagement. AR-based learning improves visualisation and engagement but lacks personalisation, while AI-based learning provides adaptive features but lacks immersive visualisation.

In contrast, the integration of AR and AI combines immersive visualisation with adaptive learning capabilities, resulting in higher learning outcomes, greater engagement, improved personalisation, and better user experience. This indicates a synergistic effect**,** where the combined use of technologies produces greater impact than individual implementations.

Conceptual Model Discussion
Based on the findings, this study proposes a conceptual framework in which learning effectiveness is influenced by the interaction of three main components:

1. Augmented Reality (AR) enhances visual cognition and engagement through immersive 3D interaction.
2. Artificial Intelligence (AI) supports adaptive learning and personalised feedback.
3. Graphic Design Principles ensure effective communication, usability, and visual clarity.

These components interact within the learning process to support experiential learning, improve cognitive engagement, and enhance user experience. The integration of these elements leads to improved learning quality, higher engagement, and better satisfaction.

This model contributes theoretically by demonstrating the importance of integrating technology, pedagogy, and visual design in educational innovation.

Limitations and Future Research

Despite its contributions, this study has several limitations. First, the research was conducted within a single institution with a limited sample size, which may affect generalizability. Second, the implementation period was relatively short, limiting the observation of long-term learning effects. Third, the effectiveness of the system may depend on technological infrastructure, such as device capability and internet access. Finally, the study focused specifically on graphic design education, limiting its applicability to other disciplines.

Future research is recommended to expand the study across multiple institutions and disciplines to improve generalizability. Longitudinal studies are needed to examine long-term learning outcomes and skill development. Further research should also explore the integration of advanced AI technologies, such as generative AI and learning analytics, to enhance personalisation. Additionally, experimental designs with control groups are suggested to provide stronger causal evidence. Finally, future studies should investigate the alignment of AR–AI-based learning with industry practices to ensure relevance to professional contexts.

Synthesis

Overall, the findings confirm that the integration of AR, AI, and graphic design principles provides a comprehensive and effective approach to improving learning quality in higher education. This approach not only enhances learning outcomes but also creates a more engaging, adaptive, and meaningful learning experience.

CONCLUSION

Proposed conclusion:

This study demonstrates that integrating augmented reality, artificial intelligence, and graphic design principles can enhance learning in higher education graphic design courses. The developed media produced a significant improvement in learning outcomes, with a moderate normalised gain and a large effect size. Students also reported high engagement and positive user experience, particularly in relation to visual design and satisfaction. AR supported immersive visualisation of design concepts, while AI enabled adaptive feedback and personalised learning. Together, these technologies created a more interactive, learner-centred environment than conventional or single-technology approaches.

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