IELTech Informatics Education and Learning Technologies

Vol 1, No. 2, December 2025, pp. 87–96
doi: 10.23917/ieltech.v1i2.17546

Enhancing Programming Logic Comprehension: A Usability Study and Learning Outcome Evaluation of an AR-Integrated Interactive Book

Yusri Ardhian, Arie Setyaga Handika

Pendidikan Teknik Informatika, Universitas Muhammadiyah Surakarta

Email: yusriardhian@gmail.com

Article History:

Received: 4/8/2025
Revised: 20/10/2025
Accepted: 17/11/2025
Published: 16/12/2025

Keywords:

Augmented Reality; Programming Logic; Interactive Learning; System Usability Scale; Vocational Education

Abstract

The mastery of programming logic and algorithms is essential for vocational computer science students, yet traditional lecture-based methods often struggle to effectively convey these abstract concepts. This study aims to develop and evaluate the effectiveness of an Augmented Reality (AR)-integrated interactive book, named "LOGAM AR", designed to enhance students' comprehension of programming logic. Utilizing the Research and Development (R&D) approach with the ADDIE model, the application was developed and tested on 36 tenth-grade students. The evaluation employed the System Usability Scale (SUS) to measure user experience and a pre-test/post-test design to assess learning outcomes, comparing an experimental group using the AR tool with a control group using conventional methods. The usability evaluation yielded a SUS score of 73.2, indicating a "Good" and acceptable user experience. Furthermore, the learning outcome analysis revealed a significant disparity; the experimental group achieved a "Medium" N-Gain score of 0.60, substantially outperforming the control group's "Low" N-Gain score of 0.24. These findings demonstrate that integrating marker-based AR with physical interactive modules successfully bridges the gap between abstract theory and visual simulation, significantly improving students' algorithmic comprehension.

1 Introduction

The rapid advancement of science and technology has significantly transformed various dimensions of human life, particularly in the field of education. This technological integration has led to substantial pedagogical shifts, moving from traditional instructional methods to more dynamic and accessible learning paradigms (Beschieru et al., 2023). In order to remain relevant in this digital era, educational institutions must adapt their teaching methodologies to align with technological progress. This adaptation necessitates the strategic implementation of advanced tools and frameworks, such as artificial intelligence, virtual reality, and augmented reality, to cultivate personalized learning experiences and enhance accessibility for diverse student populations (Ayeni et al., 2024). These technological innovations offer immersive and interactive learning environments, facilitating 360° visualizations of complex concepts across various subjects, from scientific principles to medical training (Koumiti et al., 2024).

A crucial factor in this adaptation is the mastery and implementation of instructional media by educators, which ensures that learning materials are delivered effectively and efficiently. Instructional media serves as an intermediary tool designed to stimulate students' thoughts, feelings, and attention, thereby fostering a more productive learning environment both inside and outside the classroom. This approach not only facilitates comprehension and retention but also aligns with the contemporary educational landscape characterized by the rapid evolution of information and communication technologies (Leon, 2023; Singh et al., 2025). Consequently, modern educational technology, encompassing networking and digital tools, has profoundly impacted learning and teaching styles across all disciplines, thereby enhancing the quality of education through systematic application (Ghory & Ghafory, 2021). This paradigm shift underscores the increasing prevalence of e-learning, e-curricula, learning management systems, and electronic educational platforms, which integrate technology into teaching practices (Solihat et al., 2023).

In the context of vocational education (SMK), logic and algorithms constitute fundamental concepts that students must master to succeed in computer programming. Mastery of these concepts is particularly crucial for students, especially in Software Engineerning (Rekayasa Perangkat Lunak/ RPL) programs, as it cultivates essential problem-solving skills, logical reasoning, and algorithmic thinking necessary for developing computer programs and succeeding in technology-driven vocational careers (Moeis & Yunarti, 2022). However, the teaching of these subjects still relies heavily on conventional lecture-based methods. This traditional approach often results in a passive learning experience where students lack focus, become easily bored, and struggle to comprehend abstract algorithmic concepts (Ribeiro et al., 2023). Current media, such as static whiteboards and PowerPoint presentations, have proven insufficient in providing the interactive and motivating experience necessary to develop students' creativity and independence.

Augmented Reality (AR) technology offers a promising solution to these pedagogical challenges by merging virtual objects into a real-world environment in real-time. AR has significant pedagogical potential, as recognized by educational researchers worldwide, due to its ability to make abstract concepts more intuitive and interactive (Alzahrani, 2020). By integrating AR into instructional media, educators can provide a more engaging visual experience that helps students perceive and interact with complex logical structures. This immersive approach not only enhances understanding of intricate concepts but also strengthens problem-solving capabilities and critical thinking skills by providing practical experiences in a simulated environment (Tuli et al., 2022). The use of marker-based tracking in AR further allows for precise interaction, enabling students to visualize the execution of algorithms in a 3D space.

This research aims to develop an AR-integrated interactive book, specifically designed to enhance the comprehension of programming logic among vocational students. Utilizing the ADDIE development model (Analysis, Design, Development, Implementation, and Evaluation), this study focuses on the creation of the AR application. The novelty of this work lies in its comprehensive evaluation, combining a technical usability assessment through the System Usability Scale (SUS) with an analysis of its direct impact on student learning outcomes. By bridging the gap between abstract theory and visual simulation, this research evaluates whether such an innovative tool can significantly improve students' mastery of logic and algorithms compared to conventional methods.

2 Methodology

2.1 Research Design and Participants

This study employs the Research and Development (R&D) method, which is specifically designed to produce and validate the effectiveness of particular educational products (Umar et al., 2023). The selected framework is the ADDIE development model, an acronym for Analysis, Design, Development, Implementation, and Evaluation. This model was chosen due to its systematic and structured nature, providing a comprehensive workflow that ensures the developed instructional media is measurable and strictly aligned with the pedagogical needs of the target users (Criollo-C et al., 2024). The sequential phases of the ADDIE model used in this research are visually illustrated in Figure 1.

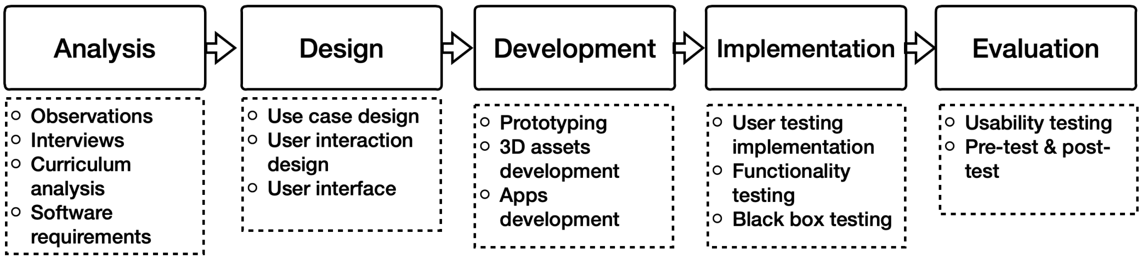

Figure 1. The ADDIE development model workflow

The development process began with the Analysis phase, involving field observations and interviews to identify core learning challenges in programming logic and algorithms. Observations revealed that traditional lecture-based methods often left students passive, necessitating more interactive solutions. This stage also included an analysis of curriculum requirements (KI/KD) and technical specifications for the hardware and software required to run Augmented Reality (AR) applications. In the Design phase, the system's architecture was mapped out through use case diagrams to define user interactions and activity diagrams to illustrate the application's workflow. Furthermore, wireframes were created to design the user interface layout. The Development phase involved the actual construction of the "LOGAM AR" application using Unity 3D as the primary engine, Vuforia SDK for AR tracking, and Blender for creating 3D animated objects. During the Implementation phase, the product was deployed in a real classroom setting to test its functional performance through black-box testing. Finally, the Evaluation phase assessed the media's usability and its impact on student learning outcomes through data analysis. This comprehensive approach ensures that the "LOGAM AR" application is not only technologically robust but also pedagogically sound, addressing specific learning deficiencies through an iterative refinement process (Çipiloğlu Yıldız & Doğan, 2024; Putri et al., 2025).

The participants involved in this study were tenth-grade students specializing in Computer and Network Engineering (TKJ). A total population of 36 students was involved, purposefully divided into two groups: a control class (18 students) taught using conventional methods and an experimental class (18 students) utilizing the AR-integrated interactive book. This comparative structure was established to provide a statistically valid measure of the media's effectiveness in a vocational school environment. Detailed demographic information of the participants is presented in Table 1.

Table 1. Demographic profile of the participants

Group	Participants	Male	Female
Control Class	18	9	9
Experimental Class	18	8	10
Total	**36**	**17**	**19**

2.2 Instruments and Data Analysis Techniques

The study utilizes a multi-dimensional approach to data collection, focusing on both technical usability and educational effectiveness. To ensure rigorous evaluation, two primary instruments were administered to the student participants: the System Usability Scale (SUS) for measuring user experience (Lewis, 2018) and a pre-test/post-test assessment for measuring learning achievement (Koumiti et al., 2024). The selection of these instruments is justified by their ability to provide a comprehensive view of how a technological intervention influences the learning process in a vocational setting. Specifically, the pre-test served to establish a baseline understanding among the groups, while the post-test facilitated the measurement of learning gains and allowed for comparative analysis between interventions (Khasawneh et al., 2023; Rincón-Flores et al., 2024).

The SUS was selected as the primary metric for assessing the interactive book's usability due to its industry-standard status as a reliable and cost-effective tool for measuring user satisfaction and ease of use (El-Sattar et al., 2024). In educational technology research, usability is a critical precursor to learning;

if a tool is difficult to navigate, it hinders the cognitive processes required for material mastery. Previous research by Baabdullah et al. (2021) emphasized that for Augmented Reality (AR) to be effective, the media must be interactive and intuitive for the learner. Similarly, the use of pre-tests and post-tests allowed for a comparative analysis between the control and experimental groups, identifying the ”Normalized Gain” (N-Gain) to determine the effectiveness of the AR-integrated book. This methodology aligns with the approach used by Tiwari et al. (2024), which utilized visualization tools to simplify abstract programming concepts for students.

The data analysis phase was conducted systematically to ensure statistical validity. First, the Aiken’s V coefficient was used to establish the validity of the instruments (Retnawati, 2016). Second, Cronbach’s Alpha was calculated to test the reliability of the test items. Third, prerequisite tests—including Kolmogorov-Smirnov for normality and Levene’s test for homogeneity—were performed to ensure the data met the requirements for parametric testing. Finally, the hypothesis was tested using the Independent Sample T-test to determine if there was a statistically significant difference in learning outcomes between students using the AR-integrated book and those taught through conventional methods.

3 Results and Discussion

3.1 Final Product: Logam AR

The final product developed in this research is an Android-based augmented reality (AR) application named ”LOGAM AR”, which is designed as an interactive learning medium to introduce basic programming logic and algorithm concepts. The name is an abbreviation derived from its core focus and technology: ”Logika dan Algoritma” (Logic and Algorithms) combined with Augmented Reality (AR). Developed using Unity 3D, Blender, and the Vuforia SDK, the application integrates virtual 3D objects with a physical interactive book to transform abstract concepts into concrete visual simulations. The system operates by scanning specific markers within the book to trigger real-time 3D animations, providing an immersive educational experience that does not require an internet connection for its primary functions.

The application utilizes marker-based tracking to bridge physical and digital learning environments. Its key features include: (1) Integrated Interface: The application contains five main navigation menus: Main Menu, Learning Objectives (KI/KD), Learning Materials, Instructions, and the AR Play Mode; (2) Interactive Learning Material: It presents textual and visual explanations of programming logic and algorithms to help students grasp theoretical concepts; (3) 3D AR Simulation: By scanning specific markers in an interactive book, the application displays real-time 3D animations. For instance, it can generate a 3D arena (map) and a virtual character; and (4) Visual Algorithmic Feedback: When students arrange physical markers correctly, the virtual character performs automated movements toward a target on the screen, providing immediate visual feedback on the students' logical sequencing.

As illustrated in Figure 2, the AR execution displays a virtual 3D arena on the screen, resembling a map, inhabited by a virtual character. The interactivity is driven by the correct arrangement of physical markers; when students successfully sequence the logic markers, the virtual character performs real-time movements toward a designated target on the map. This simulation provides immediate visual feedback on the logical sequences constructed by the student, allowing them to witness the direct outcome of their algorithmic thinking.

The primary learning objective of the LOGAM AR application is to enhance students' comprehension of fundamental programming logic and algorithms through visual simulation. By engaging with the interactive book, students are expected to achieve specific outcomes, including the ability to systematically solve problems and understand the flow of logical decision-making in programming. Ultimately, the application serves as an effective tool to increase student motivation and bridge the gap between theoretical abstract concepts and practical algorithmic application.

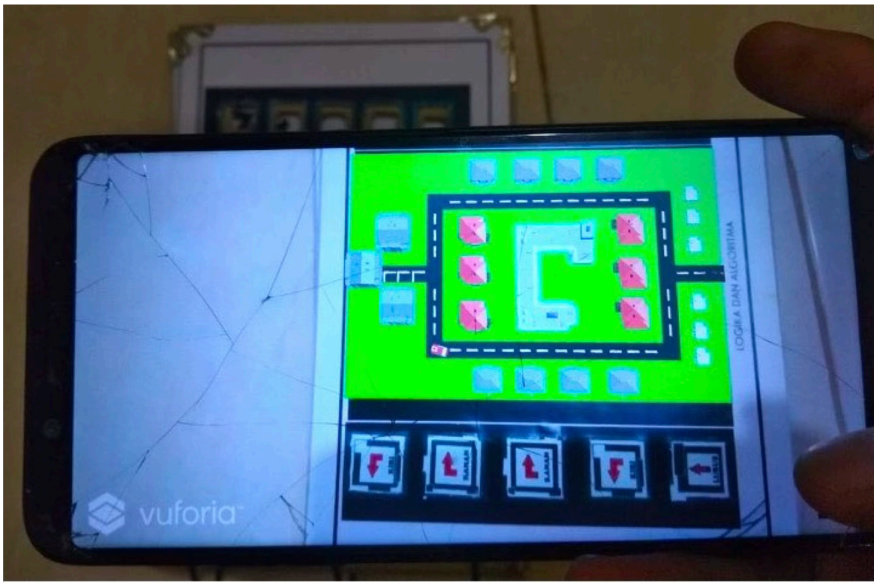

Figure 2. *LOGAM AR* application is running.

3.2 Usability Evaluation

The usability of the AR-integrated interactive book, *LOGAM AR*, was evaluated using the SUS, a robust and reliable tool for measuring the perceived ease of use of a system (Brooke, 1996). The evaluation involved participants responding to ten standardized items, resulting in a calculated mean score of 73.2 (as shown in Table 2). Based on the industry-standard benchmarks proposed by Bangor et al. (2008), a score of 73.2 falls within the ”Acceptable” range and is categorized as ”Good” in the adjective rating scale. Furthermore, this score exceeds the average SUS threshold of 68, indicating that the developed AR learning tool provides a satisfactory user experience and does not present significant barriers to interaction for the students.

Table 2. Summary of SUS scores

Questions No.	Raw	SUS Score0-4	SUS Score 0-100
1	4.11	3.11	77.8
2	1.97	3.03	75.7
3	4.03	3.03	75.7
4	2.19	2.81	70.1
5	4.22	3.22	80.6
6	2.19	2.81	70.1
7	3.86	2.86	71.5
8	2.36	2.64	66
9	4.06	3.06	76.4
10	2.28	2.72	68.1
		2.93	73.2

A more detailed item analysis reveals specific strengths and areas for improvement. The highest score was achieved by Item 5 (80.6), which measures the integration of various functions within the system. This suggests that the participants perceived the synchronization between the physical book content and the AR digital overlays as highly cohesive and well-integrated. Conversely, the lowest score was observed in Item 8 (66.0), which relates to the perceived ”cumbersomeness” of the system. This lower score might be attributed to the technical requirements of AR, such as the need to maintain a stable camera focus on markers or potential hardware limitations, which some users found slightly awkward during the initial use. Despite these minor technical challenges, the overall high scores in positive items (Q1, Q3, Q5, Q9) demonstrate that the tool is intuitive for novice learners.

The "Good" usability rating obtained in this study suggests that the AR-integrated interactive book successfully minimizes the extraneous cognitive load often associated with complex learning interfaces (Sauro, 2011). By providing a user-friendly interface, the system allows students to allocate more cognitive resources toward comprehending programming logic rather than struggling with the tool's operation. This high level of usability serves as a critical foundation for the learning outcome improvements discussed in the following section.

3.3 Learning Outcome

To evaluate the impact of the AR-integrated interactive book on students' programming logic comprehension, a pre-test and post-test design was implemented for both the control and experimental groups. Figure 3 shows a user using the LOGAM AR apps to learn logical and algorithms concepts. The assessment instrument consisted of 15 questions, with a maximum possible score of 150. Table 3 presents the descriptive statistics summarizing the students' performance. The initial data indicates a variance in the baseline knowledge between the two groups, with the experimental group demonstrating a higher pre-test mean score (85.56) compared to the control group (41.11). Both groups showed an increase in their mean scores after the learning interventions, reaching 124.44 and 67.22 for the experimental and control groups, respectively.

Figur 3. A user using the application for learning logical and algorithms concepts

Table 3. Summary of pre-test, post-test, and N-Gain Scores

Group	N	Mean Pre-test	Mean Post-test	Mean Difference	N-Gain Score	Category
Control	18	41.11	67.22	26.11	0.24	Low
Experimental	18	85.56	124.44	38.88	0.6	Medium

To accurately measure the effectiveness of the AR-integrated book while accounting for the initial baseline differences, the Normalized Gain (N-Gain) score was calculated. The N-Gain metric standardizes the actual improvement relative to the maximum possible improvement, calculated using the formula (Hake, 1999):

$$g = \frac{Posttest\ Score - Pretest\ Score}{Maximum\ Score - Pretest\ Score}$$

The analysis reveals a significant disparity in learning outcomes. The experimental group, which utilized the AR-integrated interactive book, achieved a mean *N-Gain* score of 0.60, falling into the "Medium" effectiveness category. In contrast, the control group, which utilized conventional learning methods, only achieved an N-Gain score of 0.24, which is categorized as "Low". This notable difference highlights that the integration of Augmented Reality provides a more effective pedagogical stimulus for understanding complex programming logic compared to traditional methods.

These learning outcome results strongly align with the positive usability findings (SUS score of 73.2) discussed previously. The AR-integrated book's high usability ensured that students were not hindered by technological friction, allowing them to fully engage with the interactive 3D visualizations of programming concepts. Ultimately, the cohesive integration of the AR technology facilitated a deeper cognitive comprehension, as evidenced by the superior learning gains in the experimental group.

3.4 Discussion

The primary objective of this study was to develop and evaluate the efficacy of "*LOGAM AR*", an AR-integrated interactive book designed to enhance vocational students' comprehension of programming logic and algorithms. The findings unequivocally indicate that the application achieved its pedagogical goals, demonstrating substantial improvements in both technical usability and student learning outcomes. By bridging the gap between abstract algorithmic theories and concrete visual simulations , the media provided a highly interactive environment that actively engaged students, successfully shifting the educational paradigm from passive, traditional lectures to dynamic, student-centered learning.

The usability evaluation yielded a SUS score of 73.2, placing the LOGAM AR application in the "Acceptable" range and classifying it as "Good" on the adjective rating scale. A detailed item analysis highlighted that the system's greatest strength was the seamless integration of its physical and digital functions (Item 5 score: 80.6). This cohesiveness is crucial, as (Baabdullah et al., 2021) emphasize that effective AR in education relies heavily on intuitive and interactive media design to foster positive learning experiences. However, the lowest score, which pertained to the system's perceived "cumbersomeness" (Item 8 score: 66.0) , reflects the inherent technical challenges associated with marker-based AR tracking, such as the necessity to maintain camera stability and focus during operation. Despite these minor hardware-related constraints, the overarching positive user experience confirms that the application is suitable and navigable for novice users.

Beyond usability, the empirical evaluation of learning outcomes revealed a statistically significant disparity between the interventions. The experimental group, which utilized the AR-integrated book, achieved a "Medium" N-Gain score of 0.60, starkly contrasting with the "Low" N-Gain score of 0.24 recorded by the control group subjected to conventional teaching methods. This substantial gain can be attributed directly to the real-time visual feedback provided by the AR simulation. As students physically manipulated the logic markers, the immediate execution of virtual character movements on the screen allowed them to instantly validate their algorithmic sequences. This finding aligns with the research of Tuli et al. (2022) and Alzahrani (2020), which suggests that immersive AR environments make abstract concepts significantly more intuitive, thereby bolstering problem-solving capabilities and critical thinking.

The convergence of high usability scores and superior learning outcomes underscores a critical pedagogical mechanism: the reduction of extraneous cognitive load. Because the LOGAM AR application provided a user-friendly and intuitive interface, students were not burdened by technological friction or complex navigation. Instead, they could allocate their maximum cognitive resources toward mastering the intrinsic complexity of programming logic and algorithms. This illustrates that when an educational technology tool is seamlessly integrated and easy to use, it functions as a transparent conduit for learning rather than a cognitive barrier. Consequently, this cohesive technical design directly facilitated the deeper cognitive comprehension observed in the experimental group's post-test results.

While the findings of this study are highly promising, several limitations must be acknowledged. The research was conducted with a relatively small sample size of 36 vocational students within a specific

Computer and Network Engineering (TKJ) program, which may limit the broad generalizability of the results across different educational levels or disciplines. Nonetheless, the practical implications are substantial; LOGAM AR presents a viable, innovative instructional alternative for educators, moving away from static media like whiteboards and presentations. Future research should aim to validate these findings across larger, more diverse student populations. Additionally, exploring markerless AR tracking technologies could mitigate the minor cumbersomeness reported in the usability evaluation, further refining the immersive learning experience.

4 Conclusion

In conclusion, the development and implementation of the LOGAM AR application have proven to be a highly effective pedagogical intervention for teaching programming logic and algorithms. By seamlessly merging a physical interactive book with dynamic, real-time 3D visualizations, the media successfully transformed abstract and often intimidating computational concepts into accessible, engaging simulations. The study confirms that integrating marker-based AR not only delivers an intuitive user experience but also significantly accelerates students' cognitive comprehension when compared to traditional, lecture-based instructional methods. Ultimately, this research demonstrates that strategically designed AR tools can modernize vocational education by shifting the paradigm from passive information reception to an active, immersive, and student-centered learning environment.

Despite the highly positive outcomes, this study acknowledges several limitations that warrant consideration. The evaluation was conducted on a relatively small cohort of vocational students within a single academic program, which naturally restricts the broader generalizability of the findings across different educational levels or disciplines. Furthermore, the application's reliance on marker-based tracking occasionally introduced minor technical frictions, such as the need for optimal lighting and stable camera focus, which can temporarily disrupt the immersive experience. To address these constraints, future research should aim to validate these findings across larger, more diverse student populations and various subject matters. Additionally, subsequent technical developments are highly recommended to explore markerless AR tracking or Spatial Computing technologies, which could eliminate hardware-related cumbersomeness and further refine the seamless integration of digital and physical learning spaces.

References

Alzahrani, N. M. (2020). Augmented Reality: A Systematic Review of Its Benefits and Challenges in E-learning Contexts. *Applied Sciences*, *10*(16), 5660–5660. https://doi.org/10.3390/app10165660

Ayeni, O. O., Hamad, N. M. A., Chisom, O. N., Osawaru, B., & Adewusi, O. E. (2024). AI in education: A review of personalized learning and educational technology. *GSC Advanced Research and Reviews*, *18*(2), 261–271. https://doi.org/10.30574/gscarr.2024.18.2.0062

Baabdullah, A. M., Alsulaimani, A. A., Allamnakhrah, A., Alalwan, A. A., Dwivedi, Y. K., & Rana, N. P. (2021). Usage of augmented reality (AR) and development of e-learning outcomes: An empirical evaluation of students' e-learning experience. *Computers & Education*, *177*, 104383–104383. https://doi.org/10.1016/j.compedu.2021.104383

Bangor, A., Kortum, P. T., & Miller, J. T. (2008). An empirical evaluation of the system usability scale. *Intl. Journal of Human–Computer Interaction*, *24*(6), 574–594.

Beschieru, M. (Mariana), Buzu, S. (Svetlana), Lupu, O. (Olga), & Fursenco, R. (Rodica). (2023). Education Through TECHNOLOGY: Challenges and Drawbacks. *Neliti*. https://www.neliti.com/publications/624750/education-through-technology-challenges-and-drawbacks

Brooke, J. (1996). SUS-A quick and dirty usability scale. *Usability Evaluation in Industry*, *189*(194), 4–7.

Çipiloğlu Yıldız, Z., & Doğan, S. (2024). Algo-AR: Development of an Augmented Reality-Supported Tangible

Programming Tool to Improve Algorithmic Thinking Skills. *Bilişim Teknolojileri Dergisi*, *17*(2), 59–69. https://doi.org/10.17671/gazibtd.1398781

Criollo-C, S., Guerrero-Arias, A., Uzcátegui, J. E. C., Arif, Y. M., Fortuna, A., Prasetya, F., & Luján□Mora, S. (2024). Improving Higher Education With the Use of Mobile Augmented Reality (MAR): A Case Study. *IEEE Access*, *12*, 139003–139017. https://doi.org/10.1109/access.2024.3465833

El-Sattar, H. K. H. A., Omar, M., & Mohamady, H. (2024). Developing a participatory research framework through serious games to promote learning for children with autism. *Frontiers in Education*, *9*. https://doi.org/10.3389/feduc.2024.1453327

Ghory, S., & Ghafory, H. (2021). The impact of modern technology in the teaching and learning process. *International Journal of Innovative Research and Scientific Studies*, *4*(3), 168–173. https://doi.org/10.53894/ijirss.v4i3.73

Hake, R. R. (1999). *Analyzing change/gain scores*. USA.

Khasawneh, Y. J. A., Khasawneh, N. A. S., & Khasawneh, M. A. S. (2023). Exploring the long-term effects: Retention and transfer of skills in gamified learning environment. *International Journal of Data and Network Science*, *8*(1), 195–200. https://doi.org/10.5267/j.ijdns.2023.10.004

Koumiti, H., Laanoui, M. D., & Selmaoui, S. (2024). *The Role of Technology in Global Learning Transformation: A Comprehensive overview*. 1–4. https://doi.org/10.1109/gast60528.2024.10520745

Leon, N. D. (2023). Localized Traditional Learning Modules in the History of Mathematics its Effect to the Learning Competency of Students. *Journal for Educators Teachers and Trainers*, *14*(2). https://doi.org/10.47750/jett.2023.14.02.050

Lewis, J. R. (2018). The System Usability Scale: Past, Present, and Future. *International Journal of Human-Computer Interaction*, *34*(7), 577–590. https://doi.org/10.1080/10447318.2018.1455307

Moeis, D., & Yunarti, S. (2022). PELATIHAN LOGIKA DAN ALGORITMA PEMROGRAMAN BAGI SISWA/I SMAN 3 MAKASSAR. *SELAPARANG Jurnal Pengabdian Masyarakat Berkemajuan*, *6*(2), 1013–1013. https://doi.org/10.31764/jpmb.v6i2.8755

Putri, E. S. A. Y., Wulandari, R. W., & Anggraini, A. (2025). Eco-Anim: Animated Learning Media to Enhance Student Outcomes in Ecology and Biodiversity. *PALAPA*, *13*(2), 176–188. https://doi.org/10.36088/palapa.v13i2.5833

Retnawati, H. (2016). Proving content validity of self-regulated learning scale (The comparison of Aiken index and expanded Gregory index). *REID (Research and Evaluation in Education)*, *2*(2), 155–164. https://doi.org/10.21831/reid.v2i2.11029

Ribeiro, M. I. C., Silva, W., & Feitosa, E. (2023). Active Learning Methodologies for Teaching Programming in Undergraduate Courses: A Systematic Mapping Study. *Informatics in Education*. https://doi.org/10.15388/infedu.2024.11

Rincón-Flores, E. G., Castano, L., Solis, S. L. G., Lopez, O. O., Rodríguez-Hernández, C. F., Lara, L. A. C., & Aldape, P. (2024). Improving the learning-teaching process through adaptive learning strategy. *Smart Learning Environments*, *11*(1). https://doi.org/10.1186/s40561-024-00314-9

Sauro, J. (2011). *A practical guide to the system usability scale: Background, benchmarks & best practices*. Measuring Usability LLC.

Singh, N., -, Prof. L., & Chhavilal. (2025). Techno-pedagogical Skills: An Essential Skill for Teacher in the Twenty-First Century. *International Journal on Science and Technology*, *16*(3). https://doi.org/10.71097/ijsat.v16.i3.6972

Solihat, D., Fadhly, F. Z., & Wihadi, M. (2023). VARIETY OF ENGLISH LEARNING MEDIA TECHNOLOGY: VOICES FROM NOVICE LEARNERS. *English Review Journal of English Education*, *11*(1), 211–218. https://doi.org/10.25134/erjee.v11i1.7580

Tiwari, A. S., Bhagat, K. K., & Λαμπρόπουλος, Γ. (2024). Designing and evaluating an augmented reality system for an engineering drawing course. *Smart Learning Environments*, *11*(1). https://doi.org/10.1186/s40561-023-00289-z

Tuli, N., Singh, G., Mantri, A., & Sharma, S. (2022). Augmented reality learning environment to aid engineering students in performing practical laboratory experiments in electronics engineering. *Smart Learning Environments*, *9*(1). https://doi.org/10.1186/s40561-022-00207-9

Umar, U., Purwanto, M. B., & Firdaus, Moch. M. A. (2023). RESEARCH AND DEVELOPMENT: AS THE PRIMARY ALTERNATIVE TO EDUCATIONAL RESEARCH DESIGN FRAMEWORKS. *JELL (Journal of English Language and Literature) STIBA-IEC Jakarta*, *8*(1), 73–82. https://doi.org/10.37110/jell.v8i01.172