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Effectiveness of gamified interactive multimedia on animation students' conceptual understanding and learning retention

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ABSTRACT

This study aims to analyze the effectiveness of integrating gamification-based interactive multimedia in enhancing students' conceptual understanding and learning retention in an Animation Techniques course. Using a quantitative quasi-experimental approach with a Non-equivalent Control Group Design, this study involved 80 students who were proportionally assigned to an Experimental Group ($n = 40$) and a Control Group ($n = 40$). Data collection instruments included conceptual understanding tests (pretest, posttest, and delayed posttest after 4 weeks), engagement observation sheets, and the Instructional Materials Motivation Survey (IMMS). Inferential analysis revealed a significantly higher N-gain score for conceptual understanding in the experimental group, at 0.76 (high category), compared with 0.43 (medium category) in the control group ($p < .001$). Furthermore, the delayed posttest demonstrated a memory retention rate of 88.4% in the experimental group, compared with 62.1% in the control group. Gamification features, such as interactive timing-curve simulations, immediate feedback, and micro-learning challenges, were empirically shown to optimize dual-coding cognitive channels and strengthen students' long-term memory retention.



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Introduction

Animation Techniques is a fundamental component of higher education curricula in Information Technology, Visual Communication Design, and Digital Arts, requiring students to integrate technical proficiency with conceptual knowledge of movement, spatial relationships, and physical dynamics. A central foundation of animation education is the 12 Basic Principles of Animation, particularly Squash and Stretch, Timing and Spacing, Anticipation, and Slow In and Slow Out, which require learners to understand how temporal adjustments, spatial transformations, and movement characteristics influence visual realism. Mastering these principles involves more than operating animation software; students must develop the ability to interpret motion parameters, anticipate movement outcomes, and translate theoretical concepts into coherent visual representations (Aschenbrenner & Schürr, 2003; Brinck & Gergle, 1998). These cognitive demands highlight the importance of instructional approaches that facilitate conceptual understanding through visualization and practical experimentation (Zulkifli et al., 2025).

Despite these requirements, conventional animation instruction frequently relies on lectures, static presentation materials, and instructor-centered demonstrations that provide limited opportunities for students to manipulate motion parameters independently. Such approaches may constrain students' understanding of the relationship between mathematical representations, including timing curves and easing functions, and their corresponding visual effects. Consequently, students may depend on repetitive trial-and-error procedures without adequately understanding the principles governing animation movements. Previous research has emphasized the relevance of multimedia elements in communicating complex visual information, although their effectiveness depends on how learners interact with the instructional content (Zhao & Zhang, 2025). These challenges indicate the need for learning environments that connect abstract animation principles with observable movement outcomes through structured interaction and immediate instructional feedback.

The Cognitive Theory of Multimedia Learning provides a theoretical foundation for addressing these instructional challenges by explaining how learners process verbal and pictorial information through separate but interconnected cognitive channels. According to this perspective, meaningful learning occurs when students actively select, organize, and integrate relevant information into coherent mental representations (Aqila et al., 2026). However, instructional materials containing excessive or poorly coordinated information may increase extraneous cognitive load and reduce the cognitive resources available for meaningful processing. Research on instructional design further suggests that effective multimedia environments should minimize unnecessary cognitive demands while supporting the integration of visual and conceptual information (Nurulwati et al., 2026). In animation education, interactive visualizations may facilitate these processes by allowing students to observe the immediate consequences of modifying movement parameters, although their actual cognitive benefits require empirical examination.

Gamification-based interactive multimedia represents a potential instructional approach that combines dynamic visualization with structured learning activities and motivational elements. Gamification involves incorporating game-design mechanisms into educational environments to encourage participation, persistence, and goal-directed learning (Febriansah et al., 2024). Within animation instruction, interactive simulations allow students to manipulate variables such as timing, spacing, elasticity, and movement trajectories while observing their visual consequences. These interactions can be complemented by progressive challenges, achievement points, badges, and immediate feedback to encourage repeated practice and active engagement. Previous studies have demonstrated the potential of gamified instructional environments to support learning participation and interaction (Wirahyuni et al., 2025). Nevertheless, the educational contribution of gamification should be distinguished conceptually from that of multimedia interactivity, as motivational mechanisms and visual manipulation may influence learning through different processes.

Beyond immediate conceptual understanding, learning retention constitutes an important indicator of instructional effectiveness because students must preserve and apply animation principles across successive production tasks. Interactive visualization may support the organization of conceptual information, whereas repeated challenges and corrective feedback may provide opportunities for retrieval practice and knowledge reinforcement. However, improvements in immediate posttest performance do not necessarily indicate that acquired knowledge will remain accessible over time. Evaluating learning retention through delayed assessments is therefore essential for determining whether instructional benefits persist beyond the initial learning period. Although previous studies have examined gamification in relation to motivation, engagement, and learning achievement, evidence concerning its association with delayed conceptual retention in technically demanding visual disciplines remains insufficiently established (Chastine et al., 2013; Moffett et al., 2009). This limitation highlights the need for comparative investigations that examine both immediate learning gains and subsequent knowledge retention.

To address this research gap, the present study investigates the effectiveness of gamification-based interactive multimedia in enhancing students' conceptual understanding and learning retention in an Animation Techniques course. Using a quasi-experimental non-equivalent control group design, the study compares students receiving instruction through gamified interactive multimedia with those experiencing conventional instruction. Conceptual understanding is assessed through pretest and posttest measurements, while learning retention is evaluated using a delayed posttest administered four weeks after the intervention (Bartolomé et al., 2011; Yu & Crawfis, 2015). The study specifically examines whether the gamified multimedia learning environment is associated with greater conceptual improvement and reduced knowledge loss over time. Its contribution lies in providing empirical evidence on the combined instructional approach within animation education, while recognizing that the design does not independently isolate the effects of individual gamification elements from those of multimedia interactivity.

Method

Research Design

This study employed a quantitative approach using a quasi-experimental design. The specific design was a Non-equivalent Control Group Design with repeated measurements (pretest, posttest, and delayed posttest). This design was selected to measure not only immediate improvement in understanding following the treatment but also the durability of students' memory retention after a four-week interval.

Table 1. Non-equivalent Control Group Design with Delayed Posttest

Group	Pretest	Treatment	Posttest	Delayed Posttest (4 weeks)
Experimental (E)	O1	X (Gamification-Based Interactive Multimedia)	O2	O5
Control (C)	O3	– (Conventional Learning / Static Slides)	O4	O6

Sample and Research Procedure

The study population comprised all third-semester students enrolled in the Animation Techniques course at Universitas Negeri Indonesia during the 2025/2026 academic year. Cluster random sampling was used to select two parallel classes as the sample, yielding 80 students divided into an Experimental Group ($n = 40$) and a Control Group ($n = 40$). A homogeneity test of initial ability showed no significant difference in pretest scores between the two groups before treatment ($p = .782$).

The experiment was conducted over six weeks. The Experimental Group learned using the interactive multimedia module "AnimaQuest," which incorporated game mechanics such as interactive micro-learning challenges, immediate feedback, experience points (XP), achievement badges, and a leaderboard. The Control Group received conventional instruction with exactly the same duration and content, delivered through lectures, instructor demonstrations using software, and static PDF modules.

Instruments and Data Analysis

Data were collected using a conceptual understanding test developed based on the revised Bloom's Taxonomy (C1–C5). The test consisted of 20 multiple-choice questions based on analyses of interactive animation clips and 5 essay questions addressing rigging and timing problem solving. Instrument validity was assessed through expert judgment by two media experts and two animation-content experts, while reliability was tested using Cronbach's alpha ($\alpha = .88$). In addition, motivation was measured using Keller's Instructional Materials Motivation Survey (IMMS) based on the ARCS model.

Data analysis was conducted using SPSS version 26. Improvement in conceptual understanding was measured using Meltzer's normalized gain (N-gain) score. Statistical prerequisite tests included the Shapiro–Wilk normality test and Levene's test of variance homogeneity. Hypothesis testing used an independent-samples t test to compare mean N-gain scores and a paired-samples t test to measure memory retention.

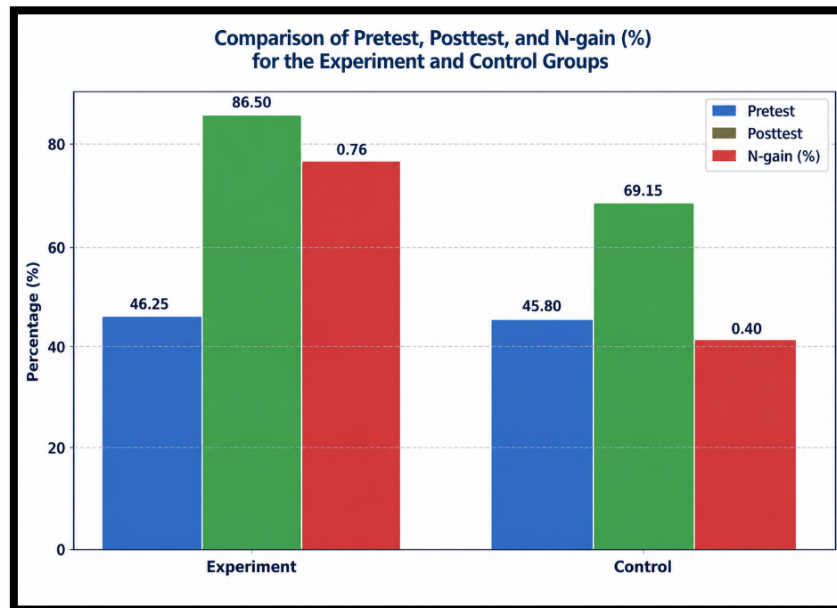
Results and Discussions

Analysis of Improvement in Conceptual Understanding (N-gain)

Based on pretest and posttest data collected from 80 students, descriptive calculations were conducted to assess the level of improvement in conceptual understanding in both study groups. The quantitative results are presented in Table 2.

Table 2. Comparison of Pretest, Posttest, and N-gain Scores for Conceptual Understanding

Group	N	Mean Pretest	Mean Posttest	Difference	N-gain	Effectiveness Category
Experimental	40	46.25	87.10	40.85	0.76	High / Effective
Control	40	45.80	69.15	23.35	0.43	Moderate / Moderately Effective



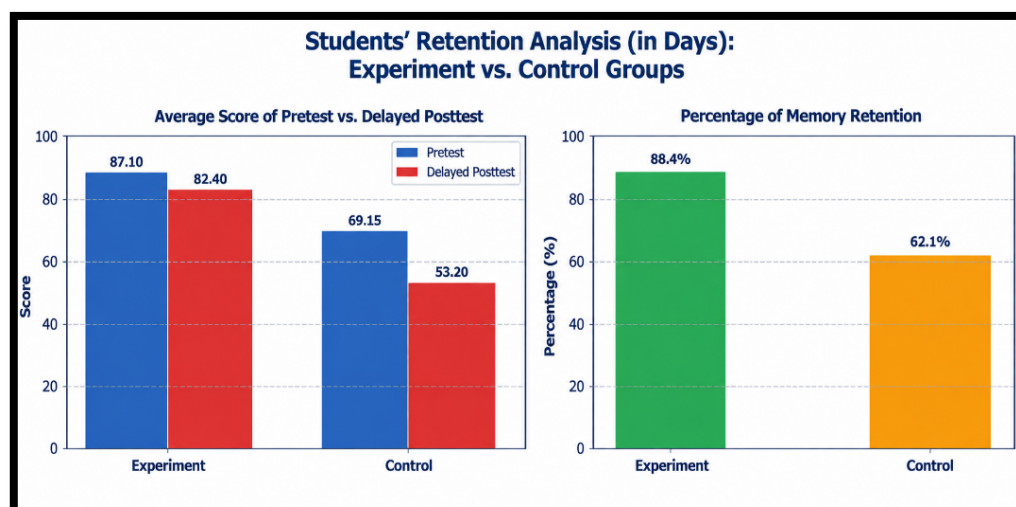
The data in Table 2 show that the Experimental Group, which learned using gamification-based interactive multimedia, achieved a mean N-gain score of 0.76, categorized as “High.” In contrast, the Control Group achieved an N-gain score of 0.43, categorized as “Moderate.” An independent-samples t test on the N-gain scores produced $t(78) = 7.842$, $p < .001$. The significance value below the alpha level of .05 indicates a statistically significant difference in conceptual understanding between the two groups.

Analysis of Long-Term Learning Retention (Delayed Posttest)

To evaluate the durability of knowledge in students’ long-term memory, a delayed posttest was administered four weeks after the initial posttest without prior notification. The learning-retention results are presented in Table 3.

Table 3. Comparison of Posttest and Delayed Posttest Scores and Retention Rates

Group	Posttest	Delayed Posttest	Score Decrease	Retention (%)	Retention Category
Experimental	87.10	82.40	4.70	88.4%	Very High
Control	69.15	53.20	15.95	62.1%	Low



The memory-retention analysis in Table 3 indicates a relatively small decrease in scores in the Experimental Group (only 4.70 points), with a knowledge-retention rate of 88.4%. In contrast, the Control Group experienced

a substantial decrease of 15.95 points, with a remaining retention rate of 62.1%. These findings indicate that interactive learning involving dynamic visual processing and gamification mechanisms was associated with stronger cognitive schemas in students' long-term memory.

The findings indicate that gamification-based interactive multimedia was associated with greater improvements in students' conceptual understanding of Animation Techniques compared with conventional instruction. The experimental group achieved a higher normalized gain (0.76) than the control group (0.43), suggesting that interactive learning environments may facilitate the comprehension of complex animation principles. From the perspective of the Cognitive Theory of Multimedia Learning, the integration of verbal explanations and dynamic visual representations may support students in connecting abstract concepts with observable movement patterns (Agustini et al., 2024). Interactive manipulation of timing, elasticity, and movement parameters may further encourage the construction of coherent mental representations by linking theoretical principles with practical animation outcomes (Castro-Alonso et al., 2019). However, these cognitive mechanisms remain theoretical interpretations because mental-model formation and cognitive load were not directly measured.

Immediate feedback represents another instructional feature that may explain the observed differences in conceptual understanding. Through the AnimaQuest module, students could identify movement inconsistencies and adjust animation parameters during learning activities, potentially reducing delays between errors and corrective actions. This mechanism may support iterative experimentation and reinforce the relationship between technical adjustments and animation outcomes. Previous research has highlighted the motivational potential of gamification elements in educational applications (Pahlevi & Mulyati, 2025). Nevertheless, the present findings cannot establish whether immediate feedback independently contributed to learning improvement, as feedback was integrated with other multimedia and gamification features. Therefore, its instructional contribution should be interpreted as part of the overall intervention rather than as an isolated causal mechanism (Buttarazzi & Urraci, 2007; Manske & Muhlhauser, 1997; Rewik et al., 2015).

Progressive learning challenges may also have contributed to students' engagement with increasingly complex animation tasks. The organization of instructional activities into sequential difficulty levels is conceptually consistent with Vygotsky's Zone of Proximal Development, which emphasizes learning support aligned with students' developing competencies. Structured challenges, experience points, and achievement badges may encourage students to complete successive tasks while receiving reinforcement for their progress (Kuncoro & Turahmat, 2025). However, the implementation of progressive levels does not necessarily demonstrate individualized scaffolding or increased intrinsic motivation. Because adaptive difficulty, time-on-task, and the motivational contribution of individual game elements were not separately analyzed, these mechanisms should be regarded as plausible explanations rather than empirically established effects (Haque, 2001; Pomaska, 2000; Szabados, 2004; Thomas, 2009).

Regarding learning retention, the experimental group demonstrated a smaller decline between the immediate posttest (87.10) and delayed posttest (82.40) than the control group, whose scores decreased from 69.15 to 53.20 after four weeks. These descriptive findings suggest that gamification-based interactive multimedia may support the maintenance of conceptual knowledge beyond the immediate instructional period. Repeated interaction with animation simulations, corrective feedback, and progressive challenges may provide opportunities for reinforcing previously acquired concepts. Nevertheless, the differences in score decline require direct inferential comparison to establish whether retention trajectories differed significantly between groups. Furthermore, retention percentages should be recalculated using a clearly defined formula to ensure consistency with the reported assessment scores (Ahmad et al., 2012; Gittens & Greaves, 2015; Güven & Feiner, 2006; Manske & Mühlhäuser, 1997).

Findings provide preliminary evidence supporting the integration of gamification-based interactive multimedia into animation education, particularly for learning activities requiring conceptual visualization and practical experimentation. However, several methodological limitations should be considered when interpreting these results. The quasi-experimental design, limited institutional context, and combined implementation of multimedia and gamification features restrict causal attribution and broader generalizability. In addition, the absence of direct cognitive-load measurements and separate analyses of motivational outcomes prevents definitive conclusions regarding the psychological mechanisms underlying learning improvement. Future research should employ multi-institutional experimental designs, factorial comparisons of gamification components, validated cognitive and motivational measures, and extended delayed assessments to clarify the mechanisms and durability of instructional effects (Ewelle et al., 2013; Hocine & Gouaich, 2011; Salomie et al., 2005; Sato et al., 2017).

Conclusions

Based on the quantitative data analysis and discussion, it can be concluded that gamification-based interactive multimedia was highly effective in improving students' conceptual understanding and learning retention in the Animation Techniques course. This improvement was indicated by an N-gain score of 0.76 (high category) in the Experimental Group, which was significantly higher than the Control Group's score of 0.43. In addition, the delayed posttest showed that the interactive media maintained a student memory-retention rate of 88.4% four weeks after treatment. The synergy between dynamic, manipulable visualization and game mechanics was associated with reduced excessive cognitive load and transformed animation learning into a more intuitive and in-depth experience. The implications of this study suggest that higher-education instructors and curriculum developers should consider adopting gamification-based interactive media as a primary support tool in digitally mediated practicum courses. Future research is recommended to expand the experimental scope to other psychological variables, such as spatial ability and problem-solving skills, and to explore the integration of Virtual Reality (VR) or Augmented Reality (AR) technologies in advanced animation learning.

References

- Agustini, N. K. T., Suyasa, P. W. A., & Wiradika, I. N. I. (2024). Pengembangan media pembelajaran interaktif berkonsep gamifikasi dengan model problem based learning pada mata pelajaran informatika. *Jurnal Pendidikan Teknologi dan Kejuruan*, 13.
- Ahmad, S. Z., Ludin, N. N. A. A. N., Ekhsan, H. M., Rosmani, A. F., & Ismail, M. H. (2012). Bijak Membaca - Applying Phonic Reading Technique and Multisensory Approach with interactive multimedia for dyslexia children. *CHUSER 2012 - 2012 IEEE Colloquium on Humanities, Science and Engineering Research*, 554–559. <https://doi.org/10.1109/CHUSER.2012.6504375>
- Aqila, Z., Salim, S., & Fitrah, N. (2026). Analisis Cognitive Theory of Multimedia Learning oleh Mayer dalam pengembangan media pembelajaran digital. *Jurnal Inovasi Pembelajaran Digital*, 4.
- Aschenbrenner, P., & Schürr, A. (2003). Generating interactive animations from visual specifications. *Proceedings - 2003 IEEE Symposium on Human Centric Computing Languages and Environments, HCC 2003*, 169–176. <https://doi.org/10.1109/HCC.2003.1260221>
- Bartolomé, N. A., Zorrilla, A. M., & Zapirain, B. G. (2011). Can game-based therapies be trusted? Is game-based education effective? A systematic review of the Serious Games for health and education. *Proceedings of CGAMES'2011 USA - 16th International Conference on Computer Games: AI, Animation, Mobile, Interactive Multimedia, Educational and Serious Games*, 275–282. <https://doi.org/10.1109/CGAMES.2011.6000353>
- Brinck, T., & Gergle, D. (1998). The design of banking Websites: Lessons from iterative design. *Proceedings - 3rd Asia Pacific Computer Human Interaction, APCHI 1998*, 386–391. <https://doi.org/10.1109/APCHI.1998.704475>
- Buttarazzi, B., & Urraci, G. (2007). Integration of multimedia design technics in 3D environment. *Proceedings of the IASTED International Conference on Graphics and Visualization in Engineering, GVE 2007*, 107–112.
- Castro-Alonso, J. C., Ayres, P., & Sweller, J. (2019). Instructional Visualizations, Cognitive Load Theory, and Visuospatial Processing. In J. C. Castro-Alonso (Ed.), *Visuospatial Processing for Education in Health and Natural Sciences* (pp. 111–143). Springer International Publishing. https://doi.org/10.1007/978-3-030-20969-8_5
- Chastine, J., Kosoris, N., & Skelton, J. (2013). A study of gesture-based first person control. *Proceedings of CGAMES 2013 USA - 18th International Conference on Computer Games: AI, Animation, Mobile, Interactive Multimedia, Educational and Serious Games*, 79–86. <https://doi.org/10.1109/CGames.2013.6632610>
- Deterding, S., Dixon, D., Khaled, R., & Nacke, L. (2011). From game design elements to gamefulness: Defining gamification. *Proceedings of the 15th International Academic MindTrek Conference: Envisioning Future Media Environments*, 9–15. <https://doi.org/10.1145/2181037.2181040>
- Ewelle, R. E., Francillette, Y., Mahdi, G., Gouaich, A., & Hocine, N. (2013). Level of detail based network adapted synchronization for cloud gaming. *Proceedings of CGAMES 2013 USA - 18th International Conference on Computer Games: AI, Animation, Mobile, Interactive Multimedia, Educational and Serious Games*, 111–118. <https://doi.org/10.1109/CGames.2013.6632616>
- Febriansah, A. T., Syaifuddin, A., & Soepriyanto, Y. (2024). Gamification developments in education: Perkembangan gamifikasi di bidang pendidikan. *Scholaria: Jurnal Pendidikan dan Kebudayaan*, 14(2), 177–186. <https://doi.org/10.24246/j.js.2024.v14.i2.p177-186>
- Gittens, C., & Greaves, J. (2015). Transforming BrowserQuest into an epidemiological tool for modelling disease dissemination. *Proceedings of CGAMES 2015 USA - 20th International Conference on Computer*

- Games: AI, Animation, Mobile, Interactive Multimedia, Educational and Serious Games, 143–148. <https://doi.org/10.1109/CGames.2015.7272972>
- Güven, S., & Feiner, S. (2006). Interaction techniques for exploring historic sites through situated media. 3DUI 2006: IEEE Symposium on 3D User Interfaces 2006 - Proceedings, 2006, 111–118. <https://doi.org/10.1109/VR.2006.87>
- Hamari, J., Koivisto, J., & Sarsa, H. (2014). Does gamification work? A literature review of empirical studies on gamification. 2014 47th Hawaii International Conference on System Sciences, 3025–3034. IEEE.
- Haque, M. E. (2001). Interactive animation and visualization in a virtual soil mechanics laboratory. Proceedings - Frontiers in Education Conference, 1, T1C/5-T1C/9.
- Hocine, N., & Gouaich, A. (2011). Therapeutic games' difficulty adaptation: An approach based on player's ability and motivation. Proceedings of CGAMES'2011 USA - 16th International Conference on Computer Games: AI, Animation, Mobile, Interactive Multimedia, Educational and Serious Games, 257–261. <https://doi.org/10.1109/CGAMES.2011.6000349>
- Keller, J. M. (2010). Motivational design for learning and performance: The ARCS model approach. Springer Science & Business Media.
- Kuncoro, C. A. M., & Turahmat, T. (2025). Strategi scaffolding pada Zone of Proximal Development (ZPD) dalam pembelajaran teks cerpen berlatar sejarah kelas XI SMA Islam Sultan Agung 3 Semarang. Jurnal Pendidikan Bahasa dan Sastra, 5(2).
- Manske, K., & Mühlhäuser, M. (1997). An open architecture for comic actor animation. Proceedings of the 5th ACM International Conference on Multimedia, MULTIMEDIA 1997, 251–259. <https://doi.org/10.1145/266180.266376>
- Manske, K., & Muhlhauser, M. (1997). Open architecture for comic actor animation. Proceedings of the ACM International Multimedia Conference & Exhibition, 251–259.
- Mayer, R. E. (2014). Cognitive theory of multimedia learning (2nd ed.). Cambridge University Press.
- Meltzer, D. E. (2002). The relationship between mathematics preparation and conceptual learning gains in physics: A possible “hidden variable” in diagnostic pretest scores. American Journal of Physics, 70(12), 1259–1268.
- Moffett, J., Rich, C., & Beck, J. (2009). Toward a causal model for automatic game balancing. Proceedings of CGAMES 2009 USA - 14th International Conference on Computer Games: AI, Animation, Mobile, Interactive Multimedia, Educational and Serious Games, 47–54.
- Nurulwati, Rozaton, R., Elisa, E., Wahyuni, A., Saputri, M., & Hamid, A. (2026). Pengaruh model pembelajaran PBL berbantuan Liveworksheet terhadap kemampuan berpikir kritis siswa SMA. Relativitas: Jurnal Riset Inovasi Pembelajaran Fisika, 9(2). <https://doi.org/10.29103/relativitas.v9i2.25127>
- Pahlevi, R., & Mulyati, S. (2025). Analisis pengaruh elemen gamifikasi pada aplikasi pembelajaran terhadap motivasi belajar siswa SMA. Jurnal Indonesia: Manajemen Informatika dan Komunikasi, 6(1), 174–186. <https://doi.org/10.35870/jimik.v6i1.1148>
- Pomaska, G. (2000). Reconstruction of the appearance of Schloss Herborn back to 1540 and its multimedia presentation. International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives, 33, 627–634.
- Rewik, N., Peuwnuan, K., Woraratpanya, K., & Pasupa, K. (2015). Particle-flow interactive animation for painting image. Proceedings - 2015 7th International Conference on Information Technology and Electrical Engineering: Envisioning the Trend of Computer, Information and Engineering, ICITEE 2015, 237–240. <https://doi.org/10.1109/ICITEED.2015.7408948>
- Sailer, M., & Homner, L. (2020). The gamification of learning: A meta-analysis. Educational Psychology Review, 32(1), 77–112. <https://doi.org/10.1007/s10648-019-09498-w>
- Salomie, I. A., Deklerck, R., Cernea, D., Markova, A., Munteanu, A., Schelkens, P., & Cornelis, J. (2005). Special effects: Efficient and scalable encoding of the 3D metamorphosis animation with MESHGRID. Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics), 3767 LNCS, 84–95. https://doi.org/10.1007/11581772_8
- Sato, K., Nose, T., & Ito, A. (2017). Synthesis of photo-realistic facial animation from text based on HMM and DNN with animation unit. Smart Innovation, Systems and Technologies, 64, 29–36. https://doi.org/10.1007/978-3-319-50212-0_4
- Suhartono, A., & Wibowo, R. (2022). Efektivitas media pembelajaran interaktif dalam pendidikan vokasi seni digital. Jurnal Teknologi Pendidikan Indonesia, 14(2), 115–128.
- Sweller, J., Van Merriënboer, J. J., & Paas, F. (1998). Cognitive architecture and instructional design. Educational Psychology Review, 10(3), 251–296.
- Szabados, B. (2004). Interactive Outcome-Based Assessment Using Multimedia. International Journal of Engineering Education, 20(2), 141–151.
- Thomas, F., & Johnston, O. (1981). The illusion of life: Disney animation. Hyperion.

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- Thomas, M. (2009). Taking a chance on losing yourself in the game. *Digital Creativity*, 20(4), 253–275. <https://doi.org/10.1080/14626260903290265>
- Wirahyuni, K., Putrayasa, I. B., Rasna, I. W., & Suandi, I. N. (2025). Gamifikasi media dan evaluasi pembelajaran pada mata kuliah MPK Bahasa Indonesia di Universitas Pendidikan Ganesha. *Jurnal Pendidikan Bahasa dan Sastra Indonesia Undiksha*, 15(3), 293–303. <https://doi.org/10.23887/jpbsi.v15i3.104126>
- Yu, Q., & Crawfis, R. (2015). Gameplay-driven terrain generation in Scorched Earth. *Proceedings of CGAMES 2015 USA - 20th International Conference on Computer Games: AI, Animation, Mobile, Interactive Multimedia, Educational and Serious Games*, 126–130. <https://doi.org/10.1109/CGames.2015.7272969>
- Zhao, S., & Zhang, Y. (2025). Research on Multimedia Animation Elements in Information Transmission Under Internet Environment. *International Journal of Cognitive Informatics and Natural Intelligence*, 19(1). <https://doi.org/https://doi.org/10.4018/IJCINI.383734>
- Zichermann, G., & Cunningham, C. (2011). *Gamification by design: Implementing game mechanics in web and mobile apps*. O'Reilly Media.
- Zulkifli, A., Firdaus, M., Rasim, R., Sari, F. B., & Fazira, I. (2025). Prinsip animasi 3D komputer dalam film animasi dan implementasinya: Sebuah kajian literatur. *Nirmana*, 25(2), 152–164. <https://doi.org/10.9744/nirmana.25.2.152-164>