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Implementation of Learning Based on Creative Thinking Skills Using Augmented Reality to Improve Academic Achievement of Students in Computer Assembly Courses

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Abstract: This study aims to evaluate the effectiveness of implementing Creative Thinking Skills (CTS)-based learning using Augmented Reality (AR) media to improve students’ academic achievement in the Computer Assembly course. The research employed a quantitative approach with a quasi-experimental method and a one-group pretest–posttest design. The subjects consisted of 30 undergraduate students of the Information and Computer Technology Education Study Program at Universitas Negeri Medan. The instruments used included a learning outcomes test, a CTS assessment rubric, and a student satisfaction questionnaire toward AR media. The learning outcomes were analyzed using the Normalized Gain (N-Gain) test, while the CTS scores were examined using a paired t-test, and the satisfaction data were analyzed descriptively. The findings showed that the use of AR significantly improved students’ learning outcomes with an average N-Gain value of 0.72 (high category). The students’ CTS scores also increased across all indicators—fluency, flexibility, originality, and elaboration—achieving an overall category of “highly creative.” Furthermore, the average satisfaction score of 4.26 (out of 5) indicated that students were very satisfied with AR-based learning. These results demonstrate that integrating AR media with CTS-based learning effectively enhances both academic performance and creative thinking abilities. Therefore, this model is recommended for use in other technology and vocational courses to promote innovation and deeper conceptual understanding.

Keywords: Augmented Reality, Creative Thinking Skills, N-Gain, Computer Assembly, Academic Achievement

1. Introduction

The development of information and communication technology (ICT) from 2020 to the present has accelerated the transformation of education towards a more digital, interactive, and adaptive learning system. Higher education institutions are required to integrate technology into the learning process in order to develop 21st-century skills, especially higher order thinking skills, such as critical, creative, communicative, and collaborative thinking [1][2]. Among these skills, Creative Thinking Skills (CTS) play an important role in encouraging students to generate new ideas, find original solutions, and adapt to complex challenges in the digital age [3]. CTS encompasses four main dimensions, namely fluency, flexibility, originality, and elaboration, which synergistically form divergent and innovative thinking skills [4].

In the context of technology and vocational education, particularly in the Computer Assembly course, creative thinking skills are highly relevant. The learning process for this course not only requires cognitive abilities in understanding the functions and relationships between computer components, but also visual-spatial abilities, system analysis, and the ability to independently develop solutions to technical problems [5]. However, learning in the field of computers is still dominated by one-way lecture and demonstration methods, so that students tend to be passive and do not have the space to develop creativity and innovative thinking skills. This condition has an impact on low levels of participation, learning motivation, and student learning outcomes.

One innovation that can be used to overcome this problem is the application of Augmented Reality (AR) as an interactive learning medium. AR is a technology that combines the real world with three-dimensional (3D) virtual objects that can be viewed and manipulated through digital devices such as smartphones or tablets[6]. This technology provides an immersive and contextual learning experience, enabling students to understand abstract concepts through visualization and direct interaction [7]. In the context of computer learning, AR allows students to visualize each hardware component realistically, perform computer assembly simulations, and understand the functions and structure of the system in a more interesting and safe way [1].

A number of recent studies show that the use of AR in learning can increase student motivation, engagement, and learning outcomes. Hamzah et al. found that the application of AR in computer network learning was able to increase students' conceptual understanding by up to 25% compared to conventional methods [8]. Similar results were also reported by Barone and Caputi, who confirmed that the use of 3D modeling-based AR strengthens students' spatial visualization and creativity skills [1]. Chiu & Hwang added that the integration of AR with a creative problem-solving approach has a significant effect on improving Creative Thinking Skills, particularly in terms of fluency and originality indicators [9]. However, most studies focus on technological development or cognitive outcomes, with limited attention to the integration of Creative Thinking Skills (CTS) as a structured pedagogical approach. This study addresses this gap by combining AR technology with CTS to simultaneously improve learning outcomes and creativity in a vocational learning context.

This research is a continuation of the AR-based learning media development study conducted by Rahmadani et al., where the previous stage focused on technical design and testing using the black-box testing method with excellent results[10]. At this implementation stage, the research focus is directed at applying Creative Thinking Skills (CTS)-based learning using AR media to improve students' academic achievement in the Computer Assembly course.

This study aims to evaluate the effectiveness of integrating Creative Thinking Skills (CTS) with Augmented Reality (AR) media in improving students' academic achievement and creativity in the Computer Assembly course. Unlike previous studies [10] that focused primarily on AR development and technical validation, this research emphasizes the empirical implementation and measurement of learning effectiveness, including learning outcomes, creative thinking skills, and student satisfaction. Therefore, this study contributes by providing comprehensive evidence of the pedagogical impact of AR–CTS integration in higher education.

In addition to assessing learning outcome improvement using the N-Gain test, this study also evaluated student satisfaction levels with AR-based learning through quantitative descriptive analysis using a proven reliable instrument ($\alpha = 0.962$). Students' creative thinking skills were measured using an assessment rubric based on four CTS indicators (fluency, flexibility, originality, and elaboration). Thus, the results of this study are expected to provide empirical contributions to the development of technology-based interactive learning models that can improve learning outcomes while strengthening students' creative thinking skills in the field of information technology and computers.

Based on the background described above, the objective of this study is to determine the effectiveness of CTS-based learning using AR media in improving students' academic achievement, creative thinking skills, and learning satisfaction.

2. Research Method

2.1. Research Design

This study used a quantitative approach with a quasi-experimental method and a one-group pretest–posttest design. This design was used because the study focused on measuring improvements in learning outcomes and creative thinking skills in the same group without using a control class [11]. This design was selected due to practical and pedagogical constraints, where all students were required to receive the same instructional treatment to ensure equal learning opportunities. In addition, the study focused on measuring learning improvement within the same group, making the one-group pretest–posttest design appropriate for evaluating intervention effectiveness in a real classroom setting [11]. The design model is shown as follows:

$$O_1 \rightarrow X \rightarrow O_2$$

Descriptions:

O_1 : Pretest (initial measurement of learning outcomes and CTS abilities)

X : Treatment in the form of Creative Thinking Skills (CTS)-based learning using Augmented Reality (AR) media

O_2 : Posttest (final measurement of learning outcomes and CTS abilities after learning)

This design allows researchers to see the difference in scores before and after the application of AR learning, as well as measure the level of improvement using N-Gain analysis [12].

2.2. Research Subject and Location

The study was conducted at the Faculty of Engineering, Universitas Negeri Medan, Indonesia. Thirty first-semester students enrolled in the Computer Assembly course in the 2024–2025 academic year as part of the Information Technology and Computer Education Study Program (PTIK) served as the research subjects. The subjects were selected using purposive sampling, considering that the students already had basic knowledge of computer hardware and adequate digital skills to participate in AR-based learning.

2.3. Research Procedures

This study was conducted through five main stages that were interconnected, starting from the preparation stage to data analysis. In the preparation stage, the researchers revised the Augmented Reality (AR)-based learning media that had been developed in previous studies [10]. The AR media had previously undergone a functionality test using the black-box testing method with excellent results. Next, the researchers developed a Creative Thinking Skills (CTS)-based learning toolkit that included a lesson plan, a CTS assessment rubric, and a learning outcome test instrument tailored to the learning outcomes of the Computer Assembly course. At this stage, the instruments were also validated by media experts and educational technology experts to ensure the suitability of the content and clarity of the assessment indicators.

The next stage is a pretest, which aims to measure students' initial abilities before they are given treatment. Students are given a learning outcome test to determine their basic understanding of computer assembly concepts. In addition, creative thinking skills are assessed using the Creative Thinking Skills Assessment Rubric, which covers four main aspects: fluency, flexibility, originality, and elaboration [13][14]. The pretest results will be used to compare how students' skills have changed following the introduction of AR-based learning.

The third stage is the implementation of learning (treatment), which is the implementation of learning activities using AR media integrated with the CTS approach. Learning takes place over four meetings in the Computer Assembly Laboratory. During the learning process, students are directed to interact with AR applications to explore various computer components, understand the functions of each part, and perform virtual assembly simulations. Learning activities also involved group discussions and project-based problem solving, where students were challenged to come up with creative ideas or solutions related to hardware configuration. Lecturers acted as facilitators who guided students' creative thinking processes through open-ended questions and reflection on the results of their work.

After the learning process was completed, a posttest was conducted to measure the improvement in learning outcomes and creative thinking skills of students. The learning outcome test was given in a form and level of difficulty equivalent to the pretest, while the CTS assessment was conducted again using the same rubric in order to obtain objective comparative data. In addition, students were asked to fill out a user satisfaction questionnaire regarding AR media to assess their perceptions of the aspects of ease of use, visual presentation, readability, and the effectiveness of AR in supporting their understanding of the material. This questionnaire used a five-point Likert scale with a total of 15 statements that had been tested for reliability with an α value of 0.962 (very reliable category) [15].

The final stage is data analysis, which includes descriptive and inferential analysis. The efficacy level of AR-based learning is assessed using the Normalized Gain (N-Gain) method, which divides learning result data into three categories: high ($g \geq 0.7$), medium ($0.3 \leq g < 0.7$), and poor ($g < 0.3$) [16]. If the data were normally distributed, the paired sample t-test was used to assess the student creative thinking ability data; if not, the Wilcoxon test was used. Prior to inferential analysis, normality testing was conducted using the Shapiro–Wilk test to determine whether the data were normally distributed. If the data met normality assumptions ($p > 0.05$), a paired sample t-test was applied. Otherwise, the Wilcoxon signed-rank test was used as a non-parametric alternative. Meanwhile, student satisfaction data were analyzed descriptively and quantitatively by calculating the mean value for each construct and interpreting the categories. The results of this analysis were then used to answer the research question regarding the effectiveness of learning based on Creative Thinking Skills using Augmented Reality in improving student learning outcomes and creativity in the Computer Assembly course.

2.4. Research Instruments

The research instruments used consisted of three main types, namely learning outcome tests, Creative Thinking Skills (CTS) assessment rubrics [13][14], and questionnaires on student satisfaction with Augmented Reality (AR) media. The learning outcome test was used to measure the increase in students' cognitive knowledge of computer assembly concepts before and after learning. The 20 multiple-choice questions on this exam were evaluated by experts in terms of both content and construct, and the Normalized Gain (N-Gain) formula was used to assess the degree of learning efficacy.

Students' creative thinking skills were assessed using the CTS Assessment Rubric, which was adapted from the Torrance model and tailored to the context of AR-based learning. This rubric evaluates four primary indicators: originality (originality of ideas), elaboration (development of ideas), fluency (fluency of ideas), and flexibility (flexibility of thinking) [13][14]. Each indicator is scored from 1 to 4, with a maximum total score of 16 points, which is then categorized as highly creative, creative, moderately creative, and less creative.

Meanwhile, student satisfaction with AR media was measured using a five-point Likert scale questionnaire consisting of 15 statements covering four constructs, namely ease of use, AR presentation, readability, and the role of AR in learning [17]. This instrument has been tested for reliability with a Cronbach's Alpha value of 0.962, indicating very high internal consistency. The questionnaire data were analyzed descriptively and quantitatively to obtain an overview of student satisfaction with the AR media used in learning.

2.5. Data Analysis Techniques

Descriptive and inferential statistical methods were used to analyze the study's data. The degree of student satisfaction with Augmented Reality (AR) media and the outcomes of Creative Thinking Skills (CTS) tests were described using descriptive analysis. Student satisfaction data were calculated based on the average score for each construct, then categorized into five levels of interpretation, ranging from very dissatisfied to very satisfied. By comparing pretest and posttest results using a paired sample t-test if the data was normally distributed or a Wilcoxon test if the data was not, inferential analysis was utilized to assess the improvement in student learning outcomes and creative thinking abilities. The improvement in learning outcomes was analyzed using the Normalized Gain (N-Gain) formula to determine the effectiveness of learning in high, medium, or low categories. The results of all these analyses were used to assess the extent to which Creative Thinking Skills-based learning using AR media was effective in improving student learning outcomes and creativity in the Computer Assembly course.

2.6. Instrument Validity and Reliability

To guarantee the precision and consistency of the measurement data, every instrument utilized in this study underwent validity and reliability testing. Content validity testing was conducted by three experts, consisting of two experts in the field of technology education and one expert in learning media, to assess the suitability of the indicators with the learning objectives and constructs being measured. The student satisfaction questionnaire instrument was found to be highly reliable with a Cronbach's Alpha value of 0.962, indicating that the internal consistency between the items was very high. Meanwhile, the Creative Thinking Skills (CTS) assessment rubric was tested for inter-rater reliability with a correlation coefficient of 0.89, indicating a high and consistent level of agreement among assessors. The learning outcome test was validated through expert assessment to ensure the suitability of the content and level of difficulty of the questions with the computer assembly material. Thus, all research instruments were declared valid and reliable, making them suitable for use in collecting data for this study.

3. Result and Discussions

3.1. Results of Student Satisfaction Test on Augmented Reality Media

The results of the analysis of student satisfaction questionnaire data regarding Augmented Reality (AR) media show that, overall, students have a very high level of satisfaction with AR-based learning. The average total satisfaction score is 4.26 on a scale of 5, which is interpreted as very satisfied. The construct with the highest score was the Role of AR in Learning (4.42), followed by Application Readability (4.24), AR Visual Presentation (4.23), and Ease of Use (4.15). The high reliability value of the instrument ($\alpha = 0.962$) indicates that all items on the questionnaire are consistent in measuring student satisfaction.

Table 1. Average Student Satisfaction Score for Media AR

Construct	Average Score	Category
Ease of Use	4,15	Very Good
AR Presentation	4,23	Very Good
Readability	4,24	Very Good
Role of AR in Learning	4,42	Very Good
Total Average	4,26	Very Good

These results in Table 1 indicate that students find the AR media used easy to operate, visually appealing, and effective in helping them understand computer assembly concepts. These findings are in line with the research by Hamzah et al. and Barone and Caputi [8][1], which states that AR-based learning can increase student motivation, interactivity, and understanding through realistic three-dimensional visualization. Thus, AR media can be categorized as a feasible, effective, and user-friendly learning medium.

3.2. Creative Thinking Skills (CTS) Assessment Results

The assessment of students' creative thinking skills was conducted using the CTS Assessment Rubric, which covers four main indicators: fluency, flexibility, originality, and elaboration. Based on the results of the pretest and posttest score comparison analysis in Table 2, there was a significant increase in all indicators of creative thinking skills. The overall average score increased from 9.87 (creative category) to 13,45 (highly creative category) after the implementation of AR-based learning. The highest increase occurred in the aspect of originality (originality of ideas) with an average increase of 1.05 points, followed by the aspect of elaboration (development of ideas) by 0,84 points.

Table 2. Improvement in the Average Creative Thinking Skills Score of Students

CTS Indicators	Pre-test Average	Post-test Average	Increase	Final Category
Fluency	2,77	3,56	0,79	Highly Creative
Flexibility	2,38	3,28	0,9	Highly Creative
Originality	2,31	3,36	1,05	Highly Creative
Elaboration	2,41	3,25	0,84	Highly Creative
Total	9,87	13,45	+3,58	Highly Creative

The paired sample t-test showed a significant increase in students' creative thinking abilities after the implementation of AR-based learning with a significance value of $p < 0.05$. The paired sample t-test results indicate a statistically significant improvement in students' Creative Thinking Skills, $t(29) = -12.24$, $p < 0.001$.

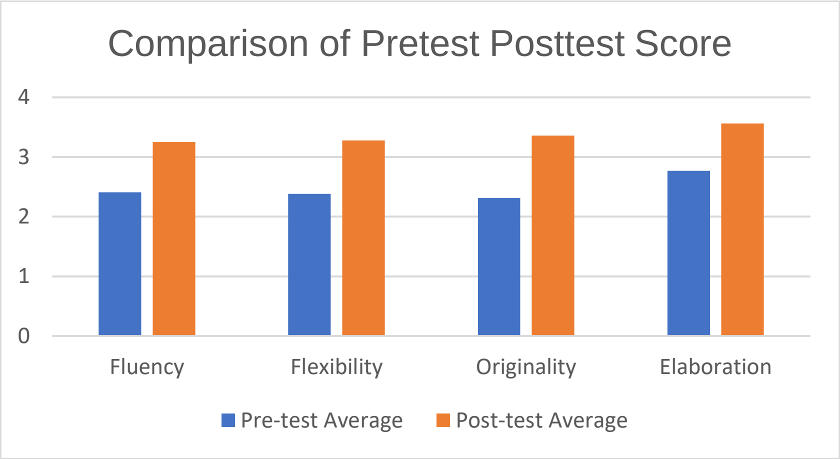

Figure 1. Comparison of Pretest and Posttest Score

These results, as shown in Figure 1. prove that the Creative Thinking Skills-based learning model integrated with AR technology can encourage students to think more creatively, generate new ideas, and develop technical solutions independently.

3.3. Learning Outcomes (N-Gain Test)

The Normalized Gain (N-Gain) exam was used to analyze student learning outcomes and assess how well AR-based learning improved comprehension of computer assembly content. The analysis results showed that the average pretest score of students was 58.2, while the average posttest score increased to 85.4. Based on the calculation, the average N-Gain was 0.72, which is in the high category.

Table 3. N-Gain Test Results Student Learning Outcomes

Parameter	Average Score	Category
Pre-test	58,2	-
Post-test	85,4	-
N-Gain	0,72	High

These results in table 3 indicate that learning based on Creative Thinking Skills using AR media is effective in improving students' academic achievement. AR learning not only strengthens students' cognitive aspects but also fosters creativity and confidence in understanding the computer assembly process.

3.4 Discussions

The results of this study generally show that the integration of Augmented Reality with the Creative Thinking Skills approach has a positive effect on student satisfaction, creativity, and learning outcomes. The high level of student satisfaction with AR media indicates that technology-based learning can increase comfort, interest, and learning effectiveness. Significant improvements in all CTS indicators show that AR not only functions as a visual aid, but also as a medium that stimulates divergent thinking processes through exploration, visualization, and experimentation of ideas.

The results of this study demonstrate that the integration of Augmented Reality (AR) with the Creative Thinking Skills (CTS) approach significantly improves students' satisfaction, creativity, and learning outcomes. This improvement is evidenced by the high N-Gain score (0.72), the significant increase in CTS scores, and the positive student satisfaction results. The effectiveness of this approach can be attributed to AR's ability to provide immersive, interactive, and visual learning experiences, which enhance students' conceptual understanding and engagement. When combined with CTS, this learning environment encourages students to generate ideas, explore multiple solutions, and develop innovative thinking. Therefore, this study contributes to the development of technology-enhanced learning by providing empirical evidence that AR–CTS integration is an effective pedagogical approach for improving both cognitive and creative skills in higher education.

In terms of learning outcomes, the high average N-Gain score (0.72) reinforces the evidence that AR learning is effective in improving students' conceptual understanding of computer assembly topics. This is in line with experiential learning theory, in which students gain a deeper understanding through direct experience and active interaction with digital learning objects [1]. Overall, the results of this study expand on previous findings [10] by providing empirical evidence that the application of AR at the implementation stage is not only technically feasible but also pedagogically effective in developing creativity and improving student learning outcomes in the field of information technology and computers.

Despite its contributions, this study has several limitations. First, the research used a one-group pretest–posttest design without a control group, which may limit the generalizability of the findings. Second, the sample size was relatively small and limited to a single study program. Future research is recommended to involve larger samples and experimental designs with control groups to strengthen the validity of the findings.

4. Conclusions

This study shows that the application of Creative Thinking Skills (CTS)-based learning using Augmented Reality (AR) media has proven to be effective in improving learning outcomes and creative thinking skills of students in Computer Assembly courses. Based on the N-Gain test results, there was an increase in learning outcomes of 0.72, which is classified as high, indicating that the use of AR media has a positive impact on students' conceptual understanding and technical skills. In addition, the CTS assessment results showed a significant increase in all indicators — fluency, flexibility, originality, and elaboration — with a final category of “very creative.”

This study demonstrates that the integration of AR and CTS is not only effective in improving academic achievement but also provides a scalable pedagogical model for technology-based learning in higher education. The findings contribute to the development of interactive and student-centered learning environments, particularly in vocational and engineering education. This approach has the potential to be adapted in other courses requiring visualization and problem-solving skills.

This AR-CTS learning model is recommended for application in other practice-based courses in the fields of technology and vocational education. Further research could expand the study by adding a control group or integrating artificial intelligence-based performance analysis to provide adaptive feedback on students' creativity development.

Reference

[1] G. Barone and E. Caputi, “3D modeling and augmented reality in education: An integrative review,” *Advances in Augmented Reality and Virtual Reality*, pp. 379–393, 2023, doi: 10.1007/978-3-031-51026-7_38.

[2] N. Yuniarti, Y. Rahmawati, M. Anwar, V. G. Al Hakim, H. Hidayat, D. Hariyanto, *et al.*, “Augmented reality-based higher order thinking skills learning media: Enhancing learning performance through self-regulated learning, digital literacy, and critical thinking skills in vocational teacher education,” *European Journal of Education*, vol. 59, no. 4, p. e12725, 2024.

[3] M. Boychuk, L. Leybyk, and O. Hudzenko, “The impact of digital tools on the development of creative thinking in students: Methodological approaches and educational strategies,” *Thai Journal of National Interest*, vol. 4, no. 17, pp. 49–58, 2024.

[4] K. M. J. Lo, *Application of creative thinking skills (CTS) in STEAM-based activities in a Hong Kong school: Instrument adopted, attitudes changed and principles derived*, Doctoral dissertation, The Education University of Hong Kong, Hong Kong, 2020.

[5] N. O. Awuor, C. Weng, I. M. Matere, J. H. Chen, D. Puspitasari, and K. N. P. Tran, “The effect of 3D-stereogram mobile AR on engineering drawing course outcomes among first-year vocational high schoolers with different spatial abilities: A Bloom’s taxonomy perspective,” *Interactive Learning Environments*, vol. 32, no. 6, pp. 2725–2743, 2024

[6] S. Dargan, S. Bansal, M. Kumar, A. Mittal, and K. Kumar, “Augmented reality: A

comprehensive review," *Archives of Computational Methods in Engineering*, vol. 30, no. 2, pp. 1057–1080, 2023.

[7] N. Mansour, C. Aras, J. K. Staarman, and S. B. M. Alotaibi, "Embodied learning of science concepts through augmented reality technology," *Education and Information Technologies*, vol. 30, no. 6, pp. 8245–8275, 2025.

[8] M. L. Hamzah, F. Rizal, and W. Simatupang, "Development of augmented reality application for learning computer network device," *International Journal of Interactive Mobile Technologies*, vol. 15, no. 12, 2021.

[9] M. C. Chiu and G. J. Hwang, "Enhancing students' critical thinking and creative thinking: An integrated mind mapping and robot-based learning approach," *Education and Information Technologies*, vol. 29, no. 17, pp. 22779–22812, 2024.

[10] R. Rahmadani, T. T. A. Putri, M. D. Mendoza, O. Hutajulu, and E. Sabrina, "Design of augmented reality-based learning media in computer assembly courses: A preliminary study," *Proceedings of the 7th International Conference on Innovation in Education, Science, and Culture (ICIESC 2025)*, Medan, Indonesia, Sept. 16, 2025.

[11] Harerimana, A., Duma, S. E., & Mtshali, N. G. (2023). Measuring perceived learning gains of undergraduate nursing students in ICT skills: One group pre-test and post-test design. *Contemporary Nurse*, *59*(2), 114-131.

[12] I. Ansori, F. Arianto, and K. Khotimah, "The effectiveness of augmented reality on students' higher order thinking skills (HOTS) in geography," *Edunesia: Jurnal Ilmiah Pendidikan*, vol. 6, no. 1, pp. 448–464, 2025.

[13] E. P. Torrance, *Torrance Tests of Creative Thinking: Norms-Technical Manual*, Lexington, MA: Personnel Press, 1974.

[14] E. D. P. Sari, R. K. Trisnawati, M. F. Agustina, D. Adiarti, and N. Noorashid, "Assessment of students' creative thinking skill on the implementation of project-based learning," *International Journal of Language Education*, vol. 7, no. 3, pp. 414–428, 2023.

[15] A. S. Abutair, M. M. Rahman, and A. B. Said, "Development and validation of the Arabic version of the social-ecological model questionnaire for patients undergoing maintenance hemodialysis," *PLoS One*, vol. 20, no. 10, p. e0333740, 2025.

[16] Hermayanti, F., & Setyasto, N. (2025). Development of E-Learning Materials Assisted by Augmented Reality on the Material of the Form of Matter and its Changes to Improve Learning Outcomes of Elementary School Students. *Jurnal Penelitian Pendidikan IPA*, *11*(1), 329-341.

[17] A. Suratno and E. W. Nugroho, "Augmented reality-based learning media design: Its compatibility to blended learning," in *Proc. 8th Int. Conf. on English Language and Teaching (ICOELT-8 2020)*, Atlantis Press, pp. 41–48, Sept. 2021.G. Barone and E. Caputi, "3D modeling and augmented reality in education: An integrative review," *Advances in Augmented Reality and Virtual Reality*, pp. 379–393, 2023, doi: 10.1007/978-3-031-51026-7_38.