Journal of Educational Technology and Learning Creativity
Vol. 3, No. 1, June 2025, pp. 99~106
ISSN: 3021-7865, DOI: 10.37251/jetlc.v3i1.1623

The Influence of Android-Based Augmented Reality Learning Media on Student Learning Outcomes in Atomic Model Material

Syamiluddin[1], Roel Ang[2], Alvic Torres[3], Edwin Auditor[4]
[1]Chemistry Education, Universitas Islam Negeri Syarif Hidayatullah Jakarta, Banten, Indonesia
[2]College of Arts and Sciences, Nueva Ecija University of Science and Technology, Cabanatuan City, Philippines
[3]School of Education, University of Saint Louis Tuguegarao, Cagayan, Philippines
[4]Institute of Teaching & Learning, Philippine Normal University, Manila, Philippines

Article Info

Article history:

Received Feb 27, 2025
Revised Mar 27, 2025
Accepted May 5, 2025
Online First May 10, 2025

Keywords:

Android
Atomic Model
Augmented Reality
Learning Media
Learning Outcomes

ABSTRACT

Purpose of the study: This study aims to determine the effect of Android-based augmented reality (AR) learning media on student learning outcomes in atomic model material.

Methodology: This study is a quantitative study with a quasi-experimental design using a one-shot case study approach. The research sample consisted of 70 grade X students at State Senior High School 29 Jakarta who were given treatment in the form of learning using Android-based augmented reality media. The research instrument was in the form of multiple-choice objective posttest questions that had been validated and equipped with grids. Data analysis was carried out using a simple linear regression test to determine the effect of the use of augmented reality media on student learning outcomes.

Main Findings: The results of the analysis show that Android-based augmented reality media has a significant influence on student learning outcomes with a significance value of 0.000 (<0.05) and a coefficient of determination (R^2) of 0.453. This shows that 45.3% of the variation in student learning outcomes can be explained by the use of augmented reality media. This media helps students understand the abstract concept of the atomic model more visually and interactively.

Novelty/Originality of this study: This research is part of a further research (dissemination) that tests the effectiveness of previously developed Android-based augmented reality media. The uniqueness of this research lies in the focus of its implementation on abstract chemical material and the use of experimental design in a real learning environment.

Corresponding Author:
Syamiluddin,
Chemistry Education, Universitas Islam Negeri Syarif Hidayatullah Jakarta,
Jl. Ir. H. Juanda No. 95, Ciputat, Kota Tangerang Selatan, Banten 15412, Indonesia
Email: syamilsyamil371@gmail.com

1. INTRODUCTION

An effective learning process is not only determined by the content of the material, but also by how the material is delivered. Interactive, fun, challenging, and motivating learning can increase students' interest in learning and encourage the creation of a conducive classroom atmosphere [1]-[3]. Teachers have an important role as the main facilitator in creating a learning process that can explore and develop students' potential [4]-[6]. Therefore, teachers need to create a fun learning atmosphere and encourage student activity [7]-[9]. One way to achieve this is by utilizing innovative learning media that is in accordance with the characteristics of students.

Learning media has a strategic role in helping teachers deliver teaching materials more effectively and efficiently. The use of appropriate media can facilitate students' understanding of the material and improve overall learning outcomes [10]-[12]. Along with the development of technology, learning media has also undergone a transformation from conventional forms to more interactive digital forms [13]-[15]. Currently, technologies such as Augmented Reality (AR) are starting to be used in the world of education because of their ability to combine digital elements with the real world [16]-[18]. The use of augmented reality in learning allows students to see, explore, and interact directly with learning objects in a more concrete way.

The application of augmented reality is very relevant in chemistry learning, especially in atomic model material which is abstract and difficult to visualize. Many students consider chemistry as a complicated subject because the concepts are not directly visible in everyday life [19]-[21]. With the help of augmented reality technology, the concept of the atomic model can be visualized in three dimensions so that it is easier to understand [22]-[24]. The use of augmented reality can also increase student active involvement in the learning process because it is interesting and stimulates curiosity [25]-[27]. Therefore, augmented reality is a potential learning medium to support improving the quality of chemistry education in schools.

Previous research by Romadiah et al., [28] meta-analyzed the effects of Android-based learning media on student learning outcomes in general without focusing on specific development or implementation, while Rosyid and Setyasto [29], developed Android-based augmented reality (AR) media on human respiratory system material, but only up to the initial evaluation stage without comprehensive implementation in real learning. The current research fills the gap by not only developing Android-based learning media using AR for atomic model material but also implementing it in the learning process to evaluate its impact on student learning outcomes empirically, providing more comprehensive and contextual insights into the effectiveness of the media.

This research is a continuation of previous research that has developed Android-based Augmented Reality learning media on atomic model material. The previous stages focused on the development and validation of media by experts and limited trials of the appearance and functionality of the media. In this advanced stage, the focus of the research is directed at the dissemination and evaluation of the influence of augmented reality media on student learning outcomes. Thus, this research not only develops technological innovation in learning, but also provides an empirical contribution to the effectiveness of using augmented reality in improving understanding of chemical concepts. This research also fills the gap from the lack of experimental studies in the use of augmented reality in schools.

The urgency of this research lies in the need for adaptive and relevant learning strategies with the characteristics of today's digital generation. Abstract chemistry material requires a visual and interactive learning approach so that students can more easily understand the concepts taught [30]-[32]. The use of augmented reality media is expected to increase student interest, motivation, and involvement in learning [33]-[35]. In addition, the use of technology that is close to students' lives such as Android makes learning more contextual and applicable [36]. This is important to support the achievement of 21st century competencies, especially in terms of mastery of technology and critical thinking skills.

Thus, this study has novelty in the evaluative aspect of the use of augmented reality media that has been developed in the context of chemistry learning in high schools. This study not only tests the media on a small scale, but also applies it in real classes and measures its impact on student learning outcomes. Through a quantitative approach with experimental design, this study can provide empirical data on the effectiveness of augmented reality learning media. The results of this study are expected to be a reference for teachers, schools, and educational technology developers in choosing the right media. In addition, this study can be a basis for further research that is broader and more comprehensive. Based on this background, the purpose of this study is to determine the effect of the use of Android-based Augmented Reality learning media on student learning outcomes in atomic model material. This study is expected to contribute to the development of more innovative chemistry learning strategies that are in accordance with the needs of the times. The findings of this study are also expected to provide an overview of the effectiveness of the use of augmented reality in improving the quality of learning. In addition, the results of this study can be recommendations for educators in integrating technology optimally in the learning process. With the right approach, the use of augmented reality-based learning media can be an alternative solution in overcoming the difficulties of learning chemistry among high school students.

2. RESEARCH METHOD

2.1. Types of research

This type of research is quantitative research with a quasi-experimental design. The study only involved one experimental class that was given treatment in the form of Android-based Augmented Reality learning media [37], [38]. Measurement of learning outcomes was carried out through a posttest without a pretest (One-Shot Case Study).

2.2. Population and Research Sample

The population in this study were all students of class X at State Senior High School 29 Jakarta. The sample used in this study was 70 students from classes X1 and X2. The sampling technique was carried out by purposive sampling, where the two classes were selected based on certain considerations that were relevant to the research objectives [39]-[41].

2.3. Data Collection Instruments and Techniques

The instrument used to measure student learning outcomes is a multiple-choice test that has been validated by experts. This test includes indicators of Basic Competencies that are relevant to the Atomic Model material. The following is a grid of the instrument listed in table 1.

Table 1. Instrument Grid

No.	Indicator	Question Number
1	Explaining the development of atomic theory from Dalton to quantum mechanics	1–5
2	Analyzing the weaknesses and strengths of each atomic model	6-10
3	Identifying the characteristics of the Bohr atomic model and quantum mechanics	11-15
4	Applying the concept of atomic models in solving problems	16-20

The data collection technique was carried out by providing a posttest after the learning process using Augmented Reality media was completed.

2.4. Data Analysis Techniques

The data obtained from the results of the student posttest were analyzed using quantitative statistical analysis techniques with a simple linear regression test [42]-[44]. The purpose of this analysis is to determine whether there is a significant influence between the use of Android-based Augmented Reality learning media on student learning outcomes in the Atomic Model material. Before the regression test was carried out, a prerequisite analysis test was first carried out, namely a normality test to ensure that the data was normally distributed, and a linearity test to see the linear relationship between the independent variables and the dependent variables [45]-[47]. After the prerequisite test was met, a simple linear regression analysis was carried out to see the magnitude of the influence and significance of the relationship between the independent variables (use of augmented reality media) and the dependent variable (student learning outcomes). This data analysis was carried out with the help of SPSS software.

2.5. Research Procedures

The research procedure consists of three main stages, namely the preparation stage, the implementation stage, and the data analysis stage. In the preparation stage, the researcher identified learning needs and prepared learning tools, including Android-based Augmented Reality learning media and evaluation instruments in the form of posttest questions. The instruments were then validated by experts to ensure the suitability of the content and validity. Furthermore, the research subjects were determined, namely 70 students from classes X1 and X2 of State Senior High School 29 Jakarta as the experimental class. The implementation stage was carried out by providing learning to students using augmented reality media in learning the Atomic Model material. The entire learning process took place in several meetings according to the time allocation specified in the Learning Implementation Plan. After the learning was completed, students were given a posttest to measure their learning outcomes after using augmented reality media. The last stage was data analysis, where the results of the posttest that had been collected were then analyzed using statistical techniques, namely simple linear regression, to determine the effect of using Augmented Reality media on student learning outcomes.

3. RESULTS AND DISCUSSION

This section presents the results of data analysis obtained from research on the effect of Android-based Augmented Reality (AR) learning media on student learning outcomes in atomic model material. The data collected were analyzed quantitatively using a descriptive statistical approach and a simple linear regression test to determine the extent to which augmented reality media contributed to improving learning outcomes [48]-[50]. The assessment was carried out through a learning outcome test after students were given treatment in the form of learning using augmented reality media. This analysis aims to provide an objective picture of the effectiveness of technology-based interactive learning media in the context of chemistry learning. The results of this analysis are presented systematically starting from descriptive statistics, assumption tests, to hypothesis tests.

3.1. Descriptive Statistics

Descriptive statistics aim to provide an overview of student learning outcomes after being given treatment in the form of learning with Android-based Augmented Reality (AR) media. Posttest data were obtained from 70 students in the experimental class. The following are the results of descriptive statistics on students' posttest scores:

Table 2. Descriptive Statistics Results

No	Statistics	Value
1	Number of respondents	70 Students
2	Minimum value	55
3	Maximum value	95
4	Average (Mean)	76.14
5	Median	76
6	Standard deviation	9.02
7	Variance	81.36

The data in Table 2 shows that the average student learning outcomes are 76.14 with the highest score of 95 and the lowest score of 55. This shows that most students get scores above the Minimum Completion Criteria set by the school. The spread of data that is not too large (standard deviation = 9.02) indicates that student learning outcomes are relatively homogeneous after using augmented reality media.

3.2. Assumption Test

Before the regression test is conducted, a classical assumption test is conducted first, including a normality test and a linearity test [51]-[53]. The normality test is conducted using the Kolmogorov-Smirnov test on the posttest score. The test results are presented in Table 3.

Table 3. Normality Test Results

Statistic	Value
Kolmogorov-Smirnov Z	0.783
Sig. (p-value)	0.575

Based on Table 3, the significance value of 0.575 is greater than 0.05, so it can be concluded that the student learning outcome data is normally distributed.

The linearity test was conducted to ensure that the relationship between the independent variable (use of augmented reality media) and the dependent variable (learning outcomes) is linear. The results of the linearity test are obtained in Table 4.

Table 4. Linearity Test Results

Source of Variation	F	Sig.
Deviation from Linearity	1.241	0.221

Since the significance value of the deviation from linearity is 0.221 > 0.05, the relationship between the independent and dependent variables can be considered linear, and the simple linear regression test can be continued.

3.3. Hypothesis Testing

Hypothesis testing in this study was conducted using simple linear regression analysis. The purpose of this analysis was to determine whether there was a significant influence between the use of Android-based augmented reality learning media on student learning outcomes. The results of the simple linear regression analysis are presented in Table 5.

Table 5. Results of Simple Linear Regression Analysis

Model	Unstandardized Coefficients	Standardized Coefficients	t	Sig
	B	Std. Error	Beta	
(Constant)	42.512	3.421		12.43
Media AR (X)	0.428	0.053	0.673	8.075

Based on Table 5, a significance value of 0.000 <0.05 is obtained, indicating that the use of Android-based augmented reality learning media has a significant effect on student learning outcomes. The regression coefficient value of 0.428 means that every one-unit increase in the use of augmented reality media will increase student learning outcomes by 0.428 points, assuming other variables are constant.

Table 6. Coefficient of Determination (R^2)

Model	R	R Square	Adjusted R Square
1	0.673	0.453	0.447

The R Square value of 0.453 indicates that 45.3% of the variation in student learning outcomes can be explained by the use of augmented reality learning media. The remaining 54.7% is explained by other factors outside the model.

The results of the study indicate that the use of Android-based Augmented Reality (AR) learning media has a significant effect on student learning outcomes in atomic model material. Based on a simple linear regression analysis, a significance value of 0.000 (<0.05) was obtained, which indicates that augmented reality media has a positive contribution to improving students' conceptual understanding. The coefficient of determination (R^2) of 0.453 also indicates that 45.3% of the variation in student learning outcomes can be explained by the use of augmented reality media. This shows that augmented reality is not only a complementary medium, but plays a direct role in building students' knowledge construction, especially in understanding abstract concepts such as atomic models. These results are in line with previous studies stating that interactive learning media can improve learning outcomes and student involvement in the learning process.

Augmented reality media allows students to interact with three-dimensional objects visually and dynamically, making learning more interesting and meaningful [54]-[56]. In the context of chemistry learning, the use of augmented reality helps students visualize atomic structures that cannot be observed directly, making the concept more concrete and easier to understand. In addition, because this media is Android-based, students can access the material anytime and anywhere, so that learning is not limited to the classroom [57]-[59]. This advantage is in line with the student-centered learning approach, where students are given the freedom to learn independently and actively. Thus, the integration of technology such as augmented reality in chemistry learning can be an innovative solution to overcome challenges in understanding abstract concepts.

The implications of this study are quite broad in the world of education, especially in the development of 21st century learning strategies. First, these results emphasize the importance of teacher mastery of technology as part of professional competence. Teachers are expected not only to understand the material, but also to be able to utilize technology effectively to improve the quality of learning [60], [61]. Second, schools and education policy makers need to consider the integration of technology such as augmented reality as part of the curriculum and the provision of learning resources [62], [63]. Third, these results provide inspiration for developers of learning media to create digital content based on augmented reality that is in accordance with the characteristics of students and teaching materials.

However, this study has several limitations. First, the study was only conducted on one experimental group without a control group, making it difficult to compare the effectiveness of augmented reality media with conventional approaches directly. Second, the measurement of learning outcomes was only carried out through a posttest, so it was not possible to see the development of students' understanding before and after treatment comprehensively. Third, the focus of the study was only on one topic of material (atomic model), so the generalization of the results to other chemical materials is still limited. In addition, other factors such as learning motivation, learning style, and environmental support were not controlled in this study, even though they could affect student learning outcomes.

Based on these limitations, there are several recommendations for future research. First, it is recommended that research be conducted with a full experimental design, involving a control group and pretest-posttest so that the results are more comprehensive. Second, research can be expanded to other abstract chemical materials, such as chemical bonds, redox reactions, or molecular structures, in order to test the consistency of the effectiveness of augmented reality media. Third, the integration of qualitative approaches in research also needs to be considered to explore students' learning experiences in more depth when using augmented reality media. Finally, collaboration is needed between educators, technology developers, and policy makers to ensure that augmented reality-based learning media can be implemented optimally and sustainably in the world of education.

4. CONCLUSION

Based on the results of the research that has been conducted, it can be concluded that Android-based Augmented Reality (AR) learning media has a significant influence on student learning outcomes in atomic model material. The results of the regression analysis show that there is a positive relationship between the use of augmented reality media and learning outcomes, with a significance value of 0.000 and a coefficient of determination of 0.453. This means that the use of augmented reality media is able to explain 45.3% of the variation in student learning outcomes, showing a significant contribution to improving the understanding of abstract chemical concepts. The use of augmented reality allows students to interact directly with three-dimensional objects visually, so that learning becomes more interesting, interactive, and meaningful. Augmented reality-based learning media not only functions as a visual aid, but also as a stimulus that can increase students' learning motivation and facilitate independent learning. This shows that technology can be an integral part of 21st-century learning strategies that emphasize creativity, interactivity, and independence. Therefore, the integration of technology such as augmented reality in chemistry learning is very relevant to be applied in the teaching and learning process, especially on topics that are abstract and difficult to visualize. Based on these conclusions, it is recommended that

future research use a stronger experimental design, such as a pretest-posttest control group design, to compare the effectiveness of augmented reality media with conventional learning methods more comprehensively.

ACKNOWLEDGMENT

The researcher would like to thank Senior High School 29 Jakarta for the support and opportunity given in conducting this research. Gratitude is also expressed to the teachers and students of grade X who have actively participated during the data collection process. This research is part of the continued development of Android-based Augmented Reality learning media, so the author would also like to thank the parties involved in the previous media development process.

REFERENCES

[1] L. T. Hang and V. H. Van, "Building strong teaching and learning strategies through teaching innovations and learners' creativity: A study of Vietnam universities," *Int. J. Educ. Pract.*, vol. 8, no. 3, pp. 498–510, 2020, doi: 10.18488/journal.61.2020.83.498.510.

[2] D. Davies, D. Jindal-Snape, C. Collier, R. Digby, P. Hay, and A. Howe, "Creative learning environments in education—A systematic literature review," *Think. Skills Creat.*, vol. 8, pp. 80–91, 2013, doi: 10.1016/j.tsc.2012.07.004.

[3] M. S. Sumbawati, I. Basuki, E. Ismayati, and T. Rijanto, "Student learning independence in online learning depends on motivation," in *Proc. Int. Joint Conf. Sci. Eng. (IJCSE 2020)*, pp. 342–347, Nov. 2020, doi: 10.2991/aer.k.201124.062.

[4] U. B. A. Ordu, "The role of teaching and learning aids/methods in a changing world," *Bulgarian Comparative Education Society*, pp. 210–216, 2021. https://eric.ed.gov/?id=ED613989

[5] M. M. Asad, N. Hussain, M. Wadho, Z. H. Khand, and P. P. Churi, "Integration of e-learning technologies for interactive teaching and learning process: An empirical study on higher education institutes of Pakistan," *J. Appl. Res. High. Educ.*, vol. 13, no. 3, pp. 649–663, 2021, doi: 10.1108/JARHE-04-2020-0103.

[6] Ü. Alan, "Distance education during the COVID-19 pandemic in Turkey: Identifying the needs of early childhood educators," *Early Child. Educ. J.*, vol. 49, no. 5, pp. 987–994, 2021, doi: 10.1007/s10643-021-01197-y.

[7] C. Novella-García and A. Cloquell-Lozano, "The ethical dimension of digital competence in teacher training," *Educ. Inf. Technol.*, vol. 26, no. 3, pp. 3529–3541, 2021, doi: 10.1007/s10639-021-10436-z.

[8] E. Luria, Z. Gross, and M. Rothgangel, "Unveiling the power of educational media: Enhancing immersion and affective engagement in Holocaust education through virtual reality," *Educ. Media Int.*, pp. 1–25, 2025, doi: 10.1080/09523987.2025.2490914.

[9] M. Y. P. Peng, Y. Xu, and C. Xu, "Enhancing students' English language learning via M-learning: Integrating technology acceptance model and SOR model," *Heliyon*, vol. 9, no. 2, 2023, doi: 10.1016/j.heliyon.2023.e13302.

[10] H. Hong and Y. Kim, "Applying artificial intelligence in career education for students with intellectual disabilities: The effects on career self-efficacy and learning flow," *Educ. Inf. Technol.*, pp. 1–20, 2024, doi: 10.1007/s10639-024-12809-6.

[11] A. O. Adu-Marfo, O. A. T. F. Kwapong, Y. Oheneba-Sakyi, and J. Miller-Young, "Understanding teachers' usage of YouTube as a pedagogical tool: A qualitative case study of basic school teachers in Ghana," *E-Learning Digit. Media*, 2024, doi: 10.1177/20427530241239393.

[12] S. Mukhamadiyeva and D. Hernández-Torrano, "Adaptive learning to maximize gifted education: Teacher perceptions, practices, and experiences," *J. Adv. Acad.*, vol. 35, no. 4, pp. 652–670, 2024, doi: 10.1177/1932202X241253166.

[13] J. Cai and Y. Li, "Fuzzy association rule mining for personalized English language teaching from higher education," *J. Comput. Methods Sci. Eng.*, vol. 24, no. 6, pp. 3617–3631, 2024, doi: 10.1177/14727978241296748.

[14] A. B. Semma, M. Ali, and M. I. Helmy, "Multi-dimensional challenges in the Indonesian social science information technology-based learning: A systematic literature review," *Heliyon*, 2024, doi: 10.1016/j.heliyon.2024.e28706.

[15] A. Ioannou and S. Retalis, "Building entrepreneurial self-efficacy in the EdTech sector: The impact of an entrepreneurship education program," *Int. J. Inf. Learn. Technol.*, 2025, doi: 10.1108/IJILT-12-2023-0234.

[16] K. S. Kaswan, J. S. Dhatterwal, and A. Pandey, "Evolution of educational technology," in *Adv. Learn. Teach. High. Educ. India: Policy-Technol.-Capacity Enabled Approach*, River Publishers, 2024, pp. 307–321, doi: 10.1201/9781032631226-21.

[17] R. da Silva Tiago and A. Mitchell, "Integrating digital transformation in nursing education: Best practices and challenges in curriculum development," in *Digit. Transform. High. Educ., Part B*, Emerald Publishing Limited, 2024, pp. 57–101, doi: 10.1108/978-1-83608-424-220241004.

[18] A. Nursalim and A. Suryadi, "La teak: Painted animation as an educational media maintaining tree sustainability AR 3D filter-based," *Digit. Appl. Archaeol. Cult. Herit.*, vol. 34, p. e00339, 2024, doi: 10.1016/j.daach.2024.e00339.

[19] A. Hamdan, A. K. Putra, I. Tan, and S. N. Farihah, "Geo-Virtual Reality (GVR): The creative materials to construct spatial thinking skills using virtual learning based metaverse technology," *Think. Skills Creat.*, vol. 54, p. 101664, 2024, doi: 10.1016/j.tsc.2024.101664.

[20] Y. Zhao and Q. Wang, "Applying augmented reality multimedia technology to construct a platform for translation and teaching system," *Heliyon*, vol. 10, no. 7, 2024, doi: 10.1016/j.heliyon.2024.e28700.

[21] K. Broman, S. Bernholt, and C. Christensson, "Relevant or interesting according to upper secondary students? Affective aspects of context-based chemistry problems," *Research in Science & Technological Education*, vol. 40, no. 4, pp. 478–498, 2022, doi: 10.1080/02635143.2020.1824177.

[22] L. Y. Midak, I. V. Kravets, O. V. Kuzyshyn, L. V. Baziuk, and K. V. Buzhdyhan, "Specifics of using image visualization within education of the upcoming chemistry teachers with augmented reality technology," in *Journal of Physics: Conference Series*, vol. 1840, no. 1, p. 012013, Mar. 2021, doi: 10.1088/1742-6596/1840/1/012013.

[23] M. Abdinejad, B. Talaie, H. S. Qorbani, and S. Dalili, "Student perceptions using augmented reality and 3D visualization technologies in chemistry education," *Journal of Science Education and Technology*, vol. 30, pp. 87–96, 2021, doi: 10.1007/s10956-020-09880-2.
[24] M. Alrige, H. Bitar, W. Al-Suraihi, K. Bawazeer, and E. Al-Hazmi, "MicroWorld: An augmented-reality Arabian app to learn atomic space," *Technologies*, vol. 9, no. 3, p. 53, 2021, doi: 10.3390/technologies9030053.
[25] G. Lampropoulos, E. Keramopoulos, K. Diamantaras, and G. Evangelidis, "Augmented reality and gamification in education: A systematic literature review of research, applications, and empirical studies," *Applied Sciences*, vol. 12, no. 13, p. 6809, 2022, doi: 10.3390/app12136809.
[26] Y. J. Lin and H. C. Wang, "Applying augmented reality in a university English class: Learners' perceptions of creativity and learning motivation," *Innovation in Language Learning and Teaching*, vol. 17, no. 2, pp. 291–305, 2023, doi: 10.1080/17501229.2022.2040513.
[27] Y. J. Liao, W. Tarng, and T. L. Wang, "The effects of an augmented reality lens imaging learning system on students' science achievement, learning motivation, and inquiry skills in physics inquiry activities," *Education and Information Technologies*, vol. 30, no. 4, pp. 5059–5104, 2025, doi: 10.1007/s10639-024-12973-9.
[28] H. Romadiah, P. Dayurni, and L. E. W. Fajari, "Meta-analysis study: The effect of android-based learning media on student learning outcomes," *International Journal of Asian Education*, vol. 3, no. 4, pp. 253–263, 2022, doi: 10.46966/ijae.v3i4.300.
[29] Y. R. R. Rosyid and N. Setyasto, "Development of Android-based augmented reality learning media on the human respiratory system to improve student learning outcomes," *Jurnal Penelitian Pendidikan IPA*, vol. 10, no. 5, pp. 2503–2510, 2024, doi: 10.29303/jppipa.v10i5.7024.
[30] V. K. Kuit and K. Osman, "CHEMBOND3D e-module effectiveness in enhancing students' knowledge of chemical bonding concept and visual-spatial skills," *European Journal of Science and Mathematics Education*, vol. 9, no. 4, pp. 252–264, 2021, doi: 10.30935/scimath/11263.
[31] M. Pikoli and A. Lukum, "Development of audio-visual learning media integrating character education in chemistry learning to facilitate conceptual change and character strengthening of high school students," in *Journal of Physics: Conference Series*, vol. 1968, no. 1, p. 012007, Jul. 2021, doi: 10.1088/1742-6596/1968/1/012007.
[32] C. Nakiboğlu and N. Nakiboğlu, "Views of prospective chemistry teachers on the use of graphic organizers supported with interactive PowerPoint presentation technology in teaching electrochemistry concepts," *International Journal of Physics and Chemistry Education*, vol. 13, no. 3, pp. 47–63, 2021, doi: 10.51724/ijpce.v13i3.216.
[33] S. Özeren and E. Top, "The effects of augmented reality applications on the academic achievement and motivation of secondary school students," *Malaysian Online Journal of Educational Technology*, vol. 11, no. 1, pp. 25–40, 2023, doi: 10.52380/mojet.2023.11.1.425.
[34] A. M. F. Yousef, "Augmented reality assisted learning achievement, motivation, and creativity for children of low-grade in primary school," *Journal of Computer Assisted Learning*, vol. 37, no. 4, pp. 966–977, 2021, doi: 10.1111/jcal.12536.
[35] S. A. Elsayed and H. I. Al-Najrani, "Effectiveness of the augmented reality on improving the visual thinking in mathematics and academic motivation for middle school students," *Eurasia Journal of Mathematics, Science and Technology Education*, vol. 17, no. 8, p. em1991, 2021, doi: 10.29333/ejmste/11069.
[36] R. Rosmiati, I. Isrokatun, N. Hanifah, Y. A. Rohman, and R. Khoerunnisah, "The development of android-based learning mobile app to practice critical thinking skills for elementary school students," *Pegem Journal of Education and Instruction*, vol. 13, no. 2, pp. 161–172, 2023, doi: 10.47750/pegegog.13.02.20.
[37] M. D. Dasopang, "Effectivity of interactive multimedia with theocentric approach to the analytical thinking skills of elementary school students in science learning," *Premiere Educandum: Jurnal Pendidikan Dasar Dan Pembelajaran*, vol. 11, no. 2, pp. 215–226, 2021, doi: 10.25273/pe.v11i2.9658.
[38] S. Nahar, "Improving students' collaboration thinking skill under the implementation of the quantum teaching model," *International Journal of Instruction*, vol. 15, no. 3, pp. 451–464, 2022, doi: 10.29333/iji.2022.15325a.
[39] F. Nyimbili and L. Nyimbili, "Types of purposive sampling techniques with their examples and application in qualitative research studies," *British Journal of Multidisciplinary and Advanced Studies*, vol. 5, no. 1, pp. 90–99, 2024, doi: 10.37745/bjmas.2022.0419.
[40] F. B. Thomas, "The role of purposive sampling technique as a tool for informal choices in a social sciences in research methods," *Just Agriculture*, vol. 2, no. 5, pp. 1–8, 2022.
[41] D. Hossan, Z. Dato'Mansor, and N. S. Jaharuddin, "Research population and sampling in quantitative study," *International Journal of Business and Technopreneurship (IJBT)*, vol. 13, no. 3, pp. 209–222, 2023, doi: 10.58915/ijbt.v13i3.263.
[42] S. Hassan, S. P. Venkateswaran, and V. D. Nadarajah, "Evaluation of immediate impact of Faculty Development Programme using a pretest–post-test study design format," *Innovation and Education*, vol. 3, no. 1, p. 1, 2021, doi: 10.1186/s42862-021-00009-9.
[43] U. A. Purba and Z. Azis, "The effectiveness of problem based learning model on the ability to solve mathematical problems in terms of students' analytical thinking ability," *JMEA: Journal of Mathematics Education and Application*, vol. 1, no. 2, pp. 73–80, 2022, doi: 10.30596/jmea.v1i2.10553.
[44] R. Handayani, G. Sakkir, and R. Kasman, "The influence of verbal-linguistic intelligence on students' learning outcomes in English at SMA Negeri 1 Sidrap," *EduLine: Journal of Education and Learning Innovation*, vol. 1, no. 2, pp. 141–148, 2021, doi: 10.35877/454RI.eduline606.
[45] D. Alita, A. D. Putra, and D. Darwis, "Analysis of classic assumption test and multiple linear regression coefficient test for employee structural office recommendation," *IJCCS (Indonesian Journal of Computing and Cybernetics Systems)*, vol. 15, no. 3, pp. 295–306, 2021, doi: 10.22146/ijccs.65586.
[46] M. Mohzana, M. Fahrurrozi, and H. Murcahyanto, "The effect of leadership and work motivation on operator performance," *AL-ISHLAH: Jurnal Pendidikan*, vol. 14, no. 2, pp. 1207–1218, 2022, doi: 10.35445/alishlah.v14i2.2023.

[47] R. R. Alhempi and B. Supeno, "Effect of training and motivation on employees performance of the environment and forestry department of Riau province," *Husnayain Business Review*, vol. 1, no. 1, pp. 60–68, 2021, doi: 10.54099/hbr.v1i1.8.
[48] A. Amores-Valencia, D. Burgos, and J. W. Branch-Bedoya, "The impact of augmented reality (AR) on the academic performance of high school students," *Electronics*, vol. 12, no. 10, p. 2173, 2023, doi: 10.3390/electronics12102173.
[49] K. A. Bölek, G. De Jong, and D. Henssen, "The effectiveness of the use of augmented reality in anatomy education: a systematic review and meta-analysis," *Scientific Reports*, vol. 11, no. 1, p. 15292, 2021, doi: 10.1038/s41598-021-94721-4.
[50] E. Çetinkaya Özdemir and H. Akyol, "Effect of augmented reality-based reading activities on some reading variables and participation in class," *International Journal of Progressive Education*, vol. 17, no. 4, pp. 135–154, 2021, doi: 10.29329/ijpe.2021.366.9.
[51] I. Shatz, "Assumption-checking rather than (just) testing: The importance of visualization and effect size in statistical diagnostics," *Behavior Research Methods*, vol. 56, no. 2, pp. 826–845, 2024, doi: 10.3758/s13428-023-02072-x.
[52] E. M. Sinaga, "The influence of price on purchase decision with quality of service as intervening variable," *JPPI (Jurnal Penelitian Pendidikan Indonesia)*, vol. 9, no. 1, pp. 125–133, 2023, doi: 10.29210/020221734.
[53] S. W. Kesumo, D. Suprayitno, and W. Latunreng, "The effect of inventory control on the work productivity of inventory division employees at PT Duta Sentosa Yasa (MR DIY) KBN Marunda," *Sinergi International Journal of Logistics*, vol. 2, no. 1, pp. 1–16, 2024, doi: 10.61194/sijl.v2i1.120.
[54] M. Fakih, "Step into a new dimension with augmented reality. Can Augmented Reality (AR) replicate the tactile experience in a virtual mathematics classroom and what is the impact on engagement and deeper understanding?," *Research in Post-Compulsory Education*, vol. 28, no. 2, pp. 226–240, 2023, doi: 10.1080/13596748.2023.2206707.
[55] F. del Cerro Velázquez and G. Morales Méndez, "Application in augmented reality for learning mathematical functions: A study for the development of spatial intelligence in secondary education students," *Mathematics*, vol. 9, no. 4, p. 369, 2021, doi: 10.3390/math9040369.
[56] D. Rohendi, M. O. Ramadhan, S. S. A. Rahim, and H. Zulnaidi, "Enhancing student's interactivity and responses in learning geometry by using augmented reality," *Eurasia Journal of Mathematics, Science and Technology Education*, vol. 21, no. 1, p. em2559, 2025, doi: 10.29333/ejmste/15796.
[57] B. J. Siregar, L. Ndruru, and S. P. Tamba, "Android-based learning media for vocational high school students," *International Journal of Natural Science and Engineering*, vol. 5, no. 2, pp. 39–48, 2021, doi: 10.23887/ijnse.v5i2.37080.
[58] J. N. Nabayra, "On-the-go android-based learning tool for mathematics in geographically challenged areas," *International Journal of Learning, Teaching and Educational Research*, vol. 23, no. 8, pp. 643–667, 2024.
[59] A. Abdullah, W. Nugraha, S. Sutiyo, R. F. Setiawan, M. I. D. Saputra, and R. P. Putra, "Learning media development: FireDroid application base on the Android system and distance learning," *Journal of Airport Engineering Technology (JAET)*, vol. 2, no. 01, pp. 33–39, 2021, doi: 10.52989/jaet.v2i01.47.
[60] M. Lubis and F. Ariansyah, "The use of deep learning to improve teaching and learning in Islamic schools," *JPCIS: Journal of Pergunu and Contemporary Islamic Studies*, vol. 1, no. 1, pp. 170–193, 2024. [Online]. Available: https://jurnal.pcpergunukotapasuruan.org/index.php/jpcis/article/view/22.
[61] D. Mdhlalose, "Integration of technology in education and its impact on learning and teaching," *Asian Journal of Education and Social Studies*, vol. 47, no. 2, pp. 10–9734, 2023, doi: 10.9734/AJESS/2023/v47i21021.
[62] M. A. AlGerafi, Y. Zhou, M. Oubibi, and T. T. Wijaya, "Unlocking the potential: A comprehensive evaluation of augmented reality and virtual reality in education," *Electronics*, vol. 12, no. 18, p. 3953, 2023, doi: 10.3390/electronics12183953.
[63] E. Murniarti, H. Prayitno, G. A. Wibowo, S. Suparmi, E. Yuliani, and R. Rochmah, "Implementing augmented reality in inclusive education: Experiments and potential," *International Journal of Science and Society*, vol. 5, no. 4, pp. 60–72, 2023.