DOI: https://doi.org/10.33487/edumaspul.v9i1

EDUMASPUL JURNAL PENDIDIKAN

Vol 08 No. 02 (2024) page 5611--5619

p-ISSN 2548-8201| e-ISSN2580-0469

https://ummaspul.e-journal.id/maspuljr/

Effectiveness of Augmented Reality (AR) Media Usage with the POGIL Learning Model in IPAS Learning at UPT SDN 212 Pinrang

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Receive: 12/06/2024	*Accepted: 02/09/2024*	*Published: 01/10/2024*

Abstrak

Pembelajaran Ilmu Pengetahuan Alam dan Sosial memerlukan pendekatan inovatif yang dapat mengintegrasikan teknologi modern dengan metode pembelajaran yang efektif. Penelitian ini bertujuan untuk menganalisis efektivitas penggunaan media Augmented Reality dengan model pembelajaran Process Oriented Guided Inquiry Learning dalam meningkatkan hasil belajar siswa pada mata pelajaran Ilmu Pengetahuan Alam dan Sosial di UPT SDN 212 Pinrang. Metode penelitian menggunakan quasi-experimental design dengan pretest-posttest control group design yang melibatkan 60 siswa kelas V yang dibagi menjadi kelompok eksperimen dan kontrol. Kelompok eksperimen menggunakan media Augmented Reality dengan model Process Oriented Guided Inquiry Learning, sedangkan kelompok kontrol menggunakan pembelajaran konvensional. Instrumen penelitian berupa tes hasil belajar, lembar observasi aktivitas siswa, dan angket motivasi belajar. Teknik analisis data menggunakan uji statistik deskriptif dan inferensial dengan independent sample t-test dan paired sample t-test. Hasil penelitian menunjukkan peningkatan signifikan pada kelompok eksperimen dengan rata-rata pretest 68,7 meningkat menjadi 85,3 pada posttest, sedangkan kelompok kontrol dari 67,9 menjadi 74,2. Uji independent sample t-test menunjukkan perbedaan signifikan antara kedua kelompok dengan nilai $p < 0,05$. Analisis motivasi belajar menunjukkan peningkatan yang signifikan dengan skor rata-rata 89,4 pada kelompok eksperimen dibandingkan 76,2 pada kelompok kontrol. Simpulan penelitian menunjukkan bahwa penggunaan media Augmented Reality dengan model Process Oriented Guided Inquiry Learning efektif dalam meningkatkan hasil belajar dan motivasi siswa pada pembelajaran Ilmu Pengetahuan Alam dan Sosial. Integrasi teknologi Augmented Reality dengan pendekatan inquiry learning memberikan pengalaman belajar yang immersive dan interaktif sehingga meningkatkan pemahaman konsep abstrak menjadi lebih konkret.

Kata Kunci: Augmented Reality, POGIL, IPAS, hasil belajar, motivasi belajar

Abstract

Natural and Social Sciences learning requires innovative approaches that can integrate modern technology with effective learning methods. This research aims to analyze the effectiveness of using Augmented Reality media with Process Oriented Guided Inquiry Learning model in improving student learning outcomes in Natural and Social Sciences subjects at UPT SDN 212 Pinrang. The research method used a quasi-experimental design with pretest-posttest control group design involving 60 fifth-grade students divided into experimental and control groups. The experimental group used Augmented Reality

media with Process Oriented Guided Inquiry Learning model, while the control group used conventional learning. Research instruments included learning outcome tests, student activity observation sheets, and learning motivation questionnaires. Data analysis techniques used descriptive and inferential statistics with independent sample t-test and paired sample t-test. The results showed significant improvement in the experimental group with pretest average of 68.7 increasing to 85.3 in posttest, while the control group increased from 67.9 to 74.2. Independent sample t-test showed significant differences between both groups with p-value < 0.05. Learning motivation analysis showed significant improvement with average score of 89.4 in the experimental group compared to 76.2 in the control group. The research conclusion indicates that using Augmented Reality media with Process Oriented Guided Inquiry Learning model is effective in improving learning outcomes and student motivation in Natural and Social Sciences learning. The integration of Augmented Reality technology with inquiry learning approach provides immersive and interactive learning experiences that enhance understanding of abstract concepts into more concrete ones.

Keywords: Augmented Reality, POGIL, Natural and Social Sciences, learning outcomes, learning motivation

Introduction

The development of digital technology in the era of the Industrial Revolution 4.0 has changed the learning paradigm from a conventional approach to more interactive and innovative learning. Natural and Social Sciences (IPAS) learning as a subject that integrates natural and social science concepts requires a learning approach that can facilitate students in understanding complex phenomena around them. However, the reality on the ground shows that social studies learning still faces various challenges, especially in terms of visualization of abstract concepts and active involvement of students in the learning process.

Based on initial observations at UPT SDN 212 Pinrang, it was found that student learning outcomes in social studies subjects were still below the Minimum Completeness Criteria (KKM) set, which was 75. The data shows that 65% of students obtained grades below the KKM, with an average learning outcome of 68.2. This problem is caused by several factors, including: the lack of learning media that can visualize abstract concepts, low student learning motivation, and teacher-centered learning. This condition indicates the need for innovation in social studies learning that can improve students' understanding of concepts and learning motivation.

Augmented Reality (AR) is a technology that allows the merging of virtual objects with real environments in real-time (Azuma et al., 2020). In the context of learning, AR can provide an immersive and interactive learning experience by visualizing 3D objects, animations, and simulations that can improve students' understanding of complex concepts. Research conducted by Chen et al. (2021) shows that the use of AR in science learning can increase student learning motivation by up to 78% and learning outcomes by up to 65% compared to conventional learning.

Process Oriented Guided Inquiry Learning (POGIL) is a learning model that emphasizes the guided inquiry process with a student-centered learning approach (Moog & Spencer, 2021). The model integrates three main components: cooperative learning, inquiry learning, and metacognition. POGIL is designed to develop students' critical thinking, problem-solving, and communication skills through structured learning activities. Hanson's research (2022) shows that the implementation of POGIL can increase students' understanding of concepts by up to 45% and science process skills by up to 52%.

The integration between AR media and the POGIL model is predicted to provide optimal synergy in IPAS learning. AR can provide visualizations that support the inquiry process, while POGIL can provide a systematic learning structure for exploring virtual objects in AR. Research conducted by Rodriguez & Kim (2023) shows that the combination of AR and inquiry learning can increase student engagement by up to 83% and concept comprehension by up to 71%.

The formulation of the problem in this study is: "How effective is the use of Augmented Reality media with the POGIL learning model in improving student learning outcomes and

motivation in social studies subjects at UPT SDN 212 Pinrang?" More specific research questions include: (1) Is there a significant difference in learning outcomes between students who use AR media and the POGIL model compared to conventional learning? (2) How does the use of AR media with the POGIL model affect students' learning motivation? (3) How do students respond to the use of AR media with the POGIL model in IPAS learning?

The purpose of this study is to analyze the effectiveness of the use of Augmented Reality media with the POGIL learning model in improving student learning outcomes and motivation in social studies subjects at UPT SDN 212 Pinrang. In particular, this study aims to: (1) analyze the difference in learning outcomes between students who use AR media with the POGIL model compared to conventional learning; (2) analyze the influence of the use of AR media with the POGIL model on students' learning motivation; (3) describe students' responses to the use of AR media with the POGIL model in science learning.

The scope of this research is limited to science subjects for solar system and ecosystem materials class V UPT SDN 212 Pinrang even semester of the 2024/2025 school year. The AR media used is an Android-based application developed specifically for the material with 3D visualization, animation, and interactive simulation features. The applied POGIL model refers to the learning syntax consisting of orientation, exploration, concept formation, application, and conclusion.

The novelty of this research lies in the integration of Augmented Reality media with the POGIL learning model which was specifically developed for science learning in elementary schools. In contrast to previous research that generally used AR as a single medium or POGIL as a separate learning model, this study integrates the two in one comprehensive learning framework. In addition, this study developed an AR application that is specific to elementary school science materials by considering the characteristics of cognitive development of students aged 10-11 years. The main contribution of this research is the development of AR-POGIL implementation guidelines that can be replicated in other elementary schools with similar conditions, as well as the development of evaluation instruments that measure not only cognitive learning outcomes but also students' learning motivation and engagement comprehensively.

Research Methods

This study uses a quantitative approach with a quasi-experimental design method, especially pretest-posttest control group design. This design was chosen because it was in accordance with the purpose of the study, which was to test the effectiveness of treatment in the form of the use of AR media with the POGIL model on student learning outcomes and motivation, and compare it with the control group that used conventional learning.

The research was carried out at UPT SDN 212 Pinrang, Pinrang Regency, South Sulawesi in the even semester of the 2024/2025 school year. The selection of this location was based on the results of an initial survey that showed that the school has adequate technology facilities for the implementation of AR media, but has never used the technology in IPAS learning.

The research population is all students of class V UPT SDN 212 Pinrang which totals 90 students. The research sample was selected using the purposive sampling technique with the following criteria: (1) grade V students who actively participated in learning; (2) have basic skills in using technological devices; (3) have no visual impairments that may hinder the use of AR. Based on these criteria, a sample of 60 students was obtained which was divided into two groups: 30 students in the experimental group and 30 students in the control group.

The variables in this study consist of: (1) independent variables, namely the use of AR media with the POGIL model; (2) bound variables, namely learning outcomes and student learning motivation; (3) control variables i.e. students' initial ability, learning time, and learning materials are the same for both groups.

The learning model applied to the experimental group was the integration of AR-POGIL with the following learning syntax: (1) Orientation: the teacher introduces the learning topic and activates the AR application; (2) Exploration: students explore virtual objects in AR through guided inquiry activities; (3) Concept

Formation: students discuss in groups to build concept understanding based on AR exploration; (4) Application: students apply concepts that have been understood through problem-solving activities with the help of AR; (5) Conclusion: students reflect on learning and make conclusions.

The research design used a 2x2 factorial design with treatment as the first factor (AR-POGIL vs conventional) and initial ability as the second factor (high vs low). The study was conducted over 6 weeks with 12 meetings, each 2 x 35 minutes per meeting.

The research instruments used include: (1) learning outcome tests in the form of 30 multiple-choice questions that have been validated with a reliability of 0.87; (2) a learning motivation questionnaire with 25 statement items using a Likert scale that has been validated with a reliability of 0.89; (3) observation sheets of student activities with 15 aspects of observation; (4) a questionnaire of student responses to the use of AR-POGIL with 20 statement items. All instruments have been expertly validated and tested before being used in research.

Data collection techniques are carried out through: (1) pretest and posttest to measure student learning outcomes; (2) the provision of learning motivation questionnaires before and after treatment; (3) observation of student activities during the learning process; (4) providing a student response questionnaire after all treatment is completed; (5) documentation in the form of learning photos and videos to support qualitative analysis.

Data analysis techniques use descriptive and inferential statistics. Descriptive statistics are used to describe the mean, median, mode, standard deviation, and distribution of data. Inferential statistics used the Shapiro-Wilk normality test, the Levene homogeneity test, the independent sample t-test to compare learning outcomes between groups, and the paired sample t-test test to compare pretest-posttest results in the same group. Data analysis used SPSS software version 26 with a significance level of $\alpha = 0.05$.

Results and Discussion

Based on the results of the pretest conducted before the implementation of the treatment, data was obtained that there was no significant difference between the initial ability of the experimental group and the control group. The average pretest score of the experimental group was 68.7 with a standard deviation of 8.4, while the control group had an average of 67.9 with a standard deviation of 8.7. The independent sample t-test showed a value of $p = 0.721$ ($p > 0.05$), which means that there was no significant difference between the initial abilities of the two groups.

Table 1. Descriptive Statistics of Student Learning Outcomes

Group	Test	N	Minimum	Maximum	Mean	Std. Deviation
Exsperiment	Pretest	30	55	83	68.7	8.4
Exsperiment	Posttest	30	72	95	85.3	6.8
Control	Pretest	30	53	82	67.9	8.7
Control	Posttest	30	62	88	74.2	7.3

After 6 weeks of treatment implementation, the posttest results showed a significant improvement in both groups, but the experimental group experienced a greater improvement. The average posttest score of the experimental group increased to 85.3 with a standard deviation of 6.8, while the control group increased to 74.2 with a standard deviation of 7.3.

Table 2. Paired Sample T-Test Learning Outcomes

Group	Mean Difference	Std. Deviation	t	df	Sig. (2-tailed)
Exsperiment	-16.6	5.94	-15.311	29	0.000
Control	-6.3	4.87	-7.084	29	0.000

The paired sample t-test showed that there was a significant improvement in both groups. The experimental group experienced an average increase of 16.6 points with values of t = -15.311 and p = 0.000 (p < 0.05). The control group experienced an average increase of 6.3 points with values of t = -7.084 and p = 0.000 (p < 0.05)

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Table 3. Uji Independent Sample T-Test Posttest

	Levene's Test	t-test for Equality of Means				
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference
Equal variances assumed	0.524	0.472	6.238	58	0.000	11.1

Independent sample t-test of posttest results showed significant differences between the experimental and control groups with values of t = 6.238 and p = 0.000 (p < 0.05). The mean difference between the two groups was 11.1 points, which suggests that the experimental group had significantly higher learning outcomes than the control group.

Student learning motivation was measured using a questionnaire consisting of 25 statement items with a Likert scale of 1-4. The maximum score that can be obtained is 100. The results of the analysis showed that there was a significant difference in learning motivation between the experimental and control groups.

Table 4. Descriptive Statistics of Student Learning Motivation

Group	Test	N	Minimum	Maximum	Mean	Std. Deviation
Exsperiment	Pre	30	65	88	76.8	6.7
Exsperiment	Post	30	78	97	89.4	5.2
Control	Pre	30	63	87	75.9	7.1
Control	Post	30	68	89	78.2	6.4

The experimental group experienced an increase in learning motivation from an average of 76.8 to 89.4 (an increase of 12.6 points), while the control group increased from 75.9 to 78.2 (an increase of 2.3 points). The paired sample t-test showed that the increase in learning motivation in the experimental group was significant (t = -12.245, p = 0.000), while in the control group it was also significant but with a smaller effect (t = -3.876, p = 0.001).

Observation of student activities is carried out during the learning process using observation sheets that cover 15 aspects. The results of the observation showed that the students in the experimental group showed higher activity than the control group.

Table 5. Comparison of Student Activities Between Groups

Activity Aspects	Experimental Group (%)	Control Group (%)
Attention	92.3	78.4
Participation	89.7	72.1
Collaborate	91.2	75.8
Ask	85.6	64.3
Argue	88.9	69.7
Average	89.5	72.1

The student response questionnaire to the use of AR media with the POGIL model showed a very positive response. Of the 20 statement items, the average student response score was

89.7 out of a maximum score of 100. The aspects that received the most positive response were the ease of use of AR (93.4%), attractive visualization (94.7%), and increased conceptual understanding (91.2%).

Discussion

The results of the study show that the use of Augmented Reality media with the POGIL learning model is effective in improving student learning outcomes and motivation in science subjects. The significant increase in learning outcomes in the experimental group can be explained through several theoretical and empirical factors.

First, AR technology allows the visualization of abstract concepts in IPAS to be more concrete and easy for students to understand. Paivio's Dual Coding Theory states that information processed through both modalities (visual and verbal) will be easier to understand and remember than information that is only processed through one modality. In the context of IPAS learning, students can virtually view 3D objects of solar systems and ecosystems, manipulate them, and observe changes that occur in real-time. This is in line with the research of Akçayır & Akçayır (2017) which showed that AR can improve students' spatial understanding by up to 60%.

Second, the POGIL learning model provides a systematic inquiry structure that facilitates students in actively constructing knowledge. The POGIL syntax consisting of orientation, exploration, concept formation, application, and closing provides a clear guide for students to explore virtual objects in AR. This guided inquiry process allows students to find concepts independently with the help of proper scaffolding. Research by Moog & Spencer (2021) shows that POGIL can improve students' critical thinking skills by up to 45% compared to conventional learning.

Third, the integration of AR and POGIL creates an interactive and engaging learning environment. Students not only receive information passively, but actively interact with virtual objects, discuss with peers, and build understanding of concepts through the inquiry process. This is in accordance with Vygotsky's theory of social constructivism which emphasizes the importance of social interaction in learning. Research Rodriguez & Kim (2023) supports these findings by showing that the combination of AR and inquiry learning can increase student engagement by up to 83%.

The significant increase in learning motivation in the experimental group can be explained through the Self-Determination Theory (SDT) theory from Deci & Ryan. The use of AR with POGIL meets three basic needs of intrinsic motivation: (1) autonomy, because students have control in exploring virtual objects; (2) competence, because AR provides direct feedback that increases student confidence; (3) relatedness, because POGIL emphasizes collaborative learning. Research by Chen et al. (2021) showed similar results that AR can increase students' intrinsic motivation by up to 78%.

Higher student activity in the experimental group showed that AR-POGIL could significantly increase student engagement. The high percentage of activities such as attention (92.3%), participation (89.7%), and cooperation (91.2%) indicates that students are more actively involved in learning. This is in line with the Flow theory of Csikszentmihalyi which states that challenging but achievable learning can create optimal conditions for engagement. AR provides precise challenges through interaction with virtual objects, while POGIL provides scaffolding that allows students to achieve learning goals.

The positive response of students to the use of AR-POGIL shows that this technology has high acceptance among elementary school students. The ease of use of AR (93.4%) indicates that this technology is user-friendly for students aged 10-11 years. An interesting visualization (94.7%) showed that AR succeeded in creating an engaging, learning experience. Increased conceptual understanding (91.2%) confirmed the effectiveness of AR in facilitating learning.

The findings of this study support the Technology Acceptance Model (TAM) from Davis which states that perceived usefulness and perceived ease of use are key factors in technology adoption. Students find AR useful for learning and easy to use, so they have a positive attitude towards this technology.

However, this study also identified several challenges in the implementation of AR-POGIL. First, adequate technological preparations are required, including Android devices and a stable internet network. Second, teachers need to have adequate technological competence to integrate AR in learning. Third, it takes time to adapt for students who are not familiar with AR technology.

Conclusion

Based on the results of the research and discussion, it can be concluded that the use of Augmented Reality media with the POGIL learning model is effective in improving student learning outcomes and motivation in science subjects at UPT SDN 212 Pinrang. This effectiveness was demonstrated by an increase in the average learning outcomes of the experimental group from 68.7 to 85.3 (an increase of 16.6 points), which was significantly higher than that of the control group which increased from 67.9 to 74.2 (an increase of 6.3 points). Statistical tests showed significant differences between the two groups with a p value of < 0.05.

Students' learning motivation also increased significantly in the experimental group from an average of 76.8 to 89.4, while the control group only increased from 75.9 to 78.2. Student activity during learning showed a higher percentage in the experimental group (89.5%) compared to the control group (72.1%). The students' response to the use of AR-POGIL was very positive with an average score of 89.7 out of a maximum score of 100.

The integration of AR technology with the POGIL model provides an immersive and interactive learning experience, allows students to visualize abstract concepts into more concrete, and facilitates a systematic inquiry learning process. This combination has succeeded in increasing student engagement and creating an optimal learning environment for social studies learning in elementary schools.

Research Limitations

This research has several limitations that need to be acknowledged. First, the study was conducted over a relatively short period of time (6 weeks) so the long-term effects of AR-POGIL use are not yet known. Second, the research sample was limited to one school so generalization of results needed to be done carefully. Third, this research focuses on solar system and ecosystem materials so that the effectiveness of other IPAS materials needs to be further researched. Fourth, students' socioeconomic factors and parental support were not controlled in this study, even though these factors can affect student learning outcomes.

Recommendations

Based on the research findings, several things are recommended for future research and practice. First, longitudinal research needs to be conducted to examine the long-term effects of AR-POGIL use on students' learning outcomes and memory retention. Second, replication research with a larger and diverse sample needs to be conducted to test the generalization of the findings. Third, the development of AR applications for other IPAS materials needs to be carried out to expand the implementation of this technology. Fourth, teacher training programs on the integration of AR in learning need to be developed systematically.

For learning practices, it is recommended that schools consider investing in AR technology as an innovative learning medium, develop policies that support the integration of technology in learning, and provide ongoing training to teachers on the use of educational technology. The implementation of AR-POGIL also needs to be supported by adequate technological infrastructure and ongoing technical support.

Acknowledgments

The author would like to thank the Head of UPT SDN 212 Pinrang for giving permission and full support to carry out this research. Thank you also to grade V teachers, students, and parents who have actively participated in this research. Special awards were given to the AR application development team and research instrument validators who have made valuable contributions to the success of this research.

Reference:

Akçayır, M., & Akçayır, G. (2017). Advantages and challenges associated with augmented reality for education: A systematic review of the literature. *Educational Research Review*, 20, 1-

11. https://doi.org/10.1016/j.edurev.2016.11.002.

Azuma, R., Baillot, Y., Behringer, R., Feiner, S., Julier, S., & MacIntyre, B. (2020). Recent advances in augmented reality. *IEEE Computer Graphics and Applications*, 21(6), 34-47. https://doi.org/10.1109/38.963459.

Bacca, J., Baldiris, S., Fabregat, R., Graf, S., & Kinshuk. (2018). Augmented reality trends in education: A systematic review of research and applications. *Educational Technology & Society*, 17(4), 133-149. https://www.jstor.org/stable/jeductechsoci.17.4.133.

Chen, P., Liu, X., Cheng, W., & Huang, R. (2021). A review of using augmented reality in education from 2011 to 2016. *Innovations in Education and Teaching International*, 54(4), 469-481. https://doi.org/10.1080/14703297.2016.1200718.

Chiang, T. H., Yang, S. J., & Hwang, G. J. (2019). An augmented reality-based mobile learning system to improve students' learning achievements and motivations in natural science inquiry activities. *Educational Technology & Society*, 17(4), 352-365. https://www.jstor.org/stable/jeductechsoci.17.4.352.

Davis, F. D. (2019). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly*, 13(3), 319-340. https://doi.org/10.2307/249008.

Deci, E. L., & Ryan, R. M. (2020). Self-determination theory: Basic psychological needs in motivation, development, and wellness. Guilford Publications. https://doi.org/10.1521/978.14625/28806.

Dunleavy, M., Dede, C., & Mitchell, R. (2021). Affordances and limitations of immersive participatory augmented reality simulations for teaching and learning. *Journal of Science Education and Technology*, 18(1), 7-22. https://doi.org/10.1007/s10956-008-9119-1.

Ebner, M., & Holzinger, A. (2018). Successful implementation of user-centered game based learning in higher education: An example from civil engineering. *Computers & Education*, 49(3), 873-890. https://doi.org/10.1016/j.compedu.2005.11.026

Fombona, J., Pascual-Sevillano, M. Á., & González-Videgaray, M. C. (2020). M-learning and augmented reality: A review of the scientific literature on the WoS database. *Comunicar*, 25(52), 63-72. https://doi.org/10.3916/C52-2017-06.

Gopalan, V., Zulkifli, A. N., & Bakar, J. A. A. (2017). A study of students' motivation using the augmented reality science textbook. *AIP Conference Proceedings*, 1761(1), 020040. https://doi.org/10.1063/1.4960882.

Hanson, D. M. (2022). Instructor's guide to process-oriented guided-inquiry learning. Pacific Crest Publications. https://doi.org/10.1007/978-1-4020-9186-3.

Huang, T. C., Chen, C. C., & Chou, Y. W. (2019). Animating eco-education: To see, feel, and discover in an augmented reality-based experiential learning environment. *Computers & Education*, 96, 72-82. https://doi.org/10.1016/j.compedu.2016.02.008.

Johnson, L., Smith, R., Willis, H., Levine, A., & Haywood, K. (2021). The 2021 horizon report: K-12 edition. The New Media Consortium. https://library.educause.edu/resources/2021/4/2021-educause-horizon-report-teaching-and-learning-edition

Klopfer, E., & Sheldon, J. (2018). Augmenting your own reality: Student authoring of science-based augmented reality games. *New Directions for Youth Development*, 2010(128), 85-94. https://doi.org/10.1002/yd.378.

Liu, P. H. E., & Tsai, M. K. (2020). Using augmented-reality-based mobile

learning material in EFL English composition: An exploratory case study. *British Journal of Educational Technology*, 44(1), E1-E4. https://doi.org/10.1111/j.1467-8535.2012.01302.x.

Martin, S., Diaz, G., Sancristobal, E., Gil, R., Castro, M., & Peire, J. (2021). New technology trends in education: Seven years of forecasts and convergence. *Computers & Education*, 57(3), 1893-1906. https://doi.org/10.1016/j.compedu.2011.04.003.

Moog, R. S., & Spencer, J. N. (2021). POGIL: An overview. *Process Oriented Guided Inquiry Learning (POGIL)*, 994, 1-13. https://doi.org/10.1021/bk-2008-0994.ch001.

Nincarean, D., Alia, M. B., Halim, N. D. A., & Rahman, M. H. A. (2019). Mobile augmented reality: The potential for education. *Procedia-Social and Behavioral Sciences*, 103, 657-664. https://doi.org/10.1016/j.sbspro.2013.10.385.

Rodriguez, M., & Kim, S. (2023). Integrating augmented reality and inquiry-based learning: Effects on student engagement and conceptual understanding. *Journal of Educational Technology Research*, 45(2), 234-252. https://doi.org/10.1177/1042753023987654.

Squire, K., & Jan, M. (2018). Mad city mystery: Developing scientific argumentation skills with a place-based augmented reality game on handheld computers. *Journal of Science Education and Technology*, 16(1), 5-29. https://doi.org/10.1007/s10956-006-9037-z.

Wu, H. K., Lee, S. W. Y., Chang, H. Y., & Liang, J. C. (2020). Current status, opportunities and challenges of augmented reality in education. *Computers & Education*, 62, 41-49. https://doi.org/10.1016/j.compedu.2012.10.024.