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THE EFFECTIVENESS OF STEAM-BASED AUGMENTED REALITY IN IMPROVING STUDENTS' SCIENCE LITERACY SKILLS

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Abstrak
Penelitian ini bertujuan untuk mendeskripsikan efektivitas Augmented Reality STEAM-Based Learning terhadap Literasi Sains Mahasiswa. Pencapaian. Penelitian Quasi-Experimental ini menggunakan desain *posttest-only control group design*. Penelitian ini dilakukan pada Mahasiswa. Sampel diambil menggunakan teknik random sampling dari kelas intake, yang terdiri dari tiga kelas paralel. Kemudian, mahasiswa dari kelas A dan B diperlakukan sebagai kelompok eksperimen, dan kelompok kontrol kelas C dan D. Mahasiswa kelompok eksperimen diajarkan menggunakan pembelajaran berbasis STEAM berbantuan AR, sedangkan kelompok kontrol, mahasiswa diajarkan dengan menerapkan metode pembelajaran konvensional. Dalam pengumpulan data, penelitian ini menggunakan tes prestasi sains dan tes literasi sains. Hasil penelitian menunjukkan bahwa penerapan pembelajaran berbasis STEAM berbantuan Augmented Reality cukup efektif dalam meningkatkan literasi sains mahasiswa, penerapan pembelajaran berbasis STEAM berbantuan Augmented Reality efektif dalam meningkatkan prestasi belajar mahasiswa, ada perbedaan hasil literasi sains dan prestasi belajar mahasiswa antara mahasiiswa yang dibelajarkan dengan menggunakan pembelajaran berbasis STEAM berbantuan Augmented Reality dengan mahasiswa yang dibelajarkan dengan menerapkan pembelajaran konvensional.

Kata Kunci: Augmented Reality; STEAM; Literasi Sains

Abstract
This study aims to describe the effectiveness of Augmented Reality STEAM-based learning on Students' Science Literacy. Achievement. This Quasi-Experimental study uses a posttest-only control group design. This study was conducted on students. The sample was taken using a random sampling technique from the intake class, which consists of three parallel classes. Then, students from classes A and B were treated as experimental groups, and control groups were classes C and D. Students in the experimental group were taught using AR-assisted STEAM-based learning, while in the control group, students were taught by applying conventional learning methods. In data collection, this study used a science achievement test and a science literacy test. The results showed that the application of Augmented Reality-assisted STEAM-based learning was quite effective in improving students' science literacy, the application of Augmented Reality-assisted STEAM-based learning was effective in improving students' learning achievement, there were differences in science literacy results and student learning achievement between students who were taught using Augmented Reality-assisted STEAM-based learning and students who were taught by implementing conventional learning.

Keyword*: Augmented Reality; STEAM; Scientific Literacy*

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INTRODUCTION

Mastery of science and technology is essential for education in the 21st century. Based on this idea, science education plays a crucial role in preparing students to develop scientific literacy (Maryanti et al., 2021). What is science? Terminologically, science is a way of thinking, a way of investigating, and a body of knowledge (Lestari et al., 2023). Meanwhile, literacy comes from the words literatus and scientia, where literatus means literacy, and scientia means science (Khotimah et al., 2021). Thus, scientific literacy refers to the ability to read, write, and communicate scientific topics and socio-scientific issues related to culture, as well as an individual's understanding of daily life and the methods for developing new knowledge in science and technology. Scientific literacy plays a crucial role in everyday life, as every individual requires reliable sources of information as a foundation for scientific reasoning in decision-making and problem-solving (Ardianto and Rubini, 2016). The relationship between functional scientific literacy and outstanding scientific achievement is very close. Academic achievement reflects actual abilities, which can be measured through tests (Shofia et al., 2024). Optimal science learning outcomes cannot be separated from the implementation of effective and relevant teaching approaches, strategies, and methods in the classroom. One of the challenges in education is the lack of effectiveness in the teaching process by educators. Science education serves as a fundamental pillar in shaping students' scientific literacy, ultimately contributing to improved science learning outcomes. Science learning should be conducted actively, with lecturers acting as facilitators who can select and implement appropriate strategies based on student characteristics, subject matter, supporting factors, and the learning environment (Chang et al., 2022).

A professional lecturer is expected to guide students to explore science and technology in this competitive era of globalization. Therefore, meaningful science learning can empower students' science literacy and achievement; and prepare prospective professional teachers in science subjects in elementary education.

Science learning does not only cover scientific concepts or scientific theories but also includes the science process taught through practicums. However, this is rarely done by teachers because there is no special time for practicums, inadequate facilities, and dense materials. Even though science practicums play an important role in the science learning process, obstacles in practice can be overcome by using alternative learning media in the form of mobile augmented reality (Koutromanos et al., 2024). Several previous Augmented Reality developments, both as module companions, supplements, and as media, have shown positive responses from science learners (Puspitasari et al., 2020) (Hapsari et al., 2018).

Augmented Reality is a form of visual integration between the physical and virtual worlds that can enrich users' perceptions of reality by adding computer-generated elements, such as three-dimensional objects (Hidajat, 2023) and text (Ibad et al., 2018). Research on the use of STEAM-based Augmented Reality on science literacy and learning outcomes is still rare. The results of the study revealed that mobile augmented reality is very effective in improving science concepts (Apriani et al., 2021). Augmented Reality as a learning medium can be used so that students can process information obtained from teachers (Rapti et al., 2023).

In addition to Augmented Reality, the current learning process must continue to develop in line with technological advances, one of which is through the integration of Science, Technology, Engineering, Arts, and Mathematics (STEAM). Research conducted by Ismail et al. (2016) shows that the implementation of STEAM-based virtual laboratories can improve scientific literacy in students. According to Morrison, as quoted by Afriana et al. (2016), STEAM-based learning has great benefits, namely training students to become problem solvers, innovators, think

independently, and have logical and critical thinking skills. This approach is also able to build creativity and literacy which are very much needed to face the challenges of the 21st century. To compete in the era of globalization, Indonesia needs to prepare competent human resources in the STEAM field, both in terms of quality and quantity (Alkhabra et al., 2023). Based on the results of this study, STEAM-based virtual laboratories have been shown to improve students' scientific literacy. Scientific literacy, along with academic achievement in science, is measured in the Programme for International Student Assessment (PISA), a global study conducted by the Organisation for Economic Co-operation and Development (OECD) (Astuti et al., 2023).

The results of the PISA survey indicate that the level of scientific literacy of Indonesian students is in the lowest category. In 2009, Indonesia was in 60th position out of 65 countries, then dropped to 64th position out of 65 countries in 2012, and returned to 63rd position out of 72 countries in 2015. This is because the learning methods applied and the learning media used are still ineffective, especially in terms of the use of practical demonstration tools (Nurdin, 2020).

Based on these problems, it is important to examine the use of learning media that can support the improvement of science literacy and students' science learning outcomes. The main question in this study is whether STEAM-based learning supported by augmented reality technology on mobile devices has a significant impact on students' science literacy.

METHOD

This study employs a quasi-experimental method. The method applied in this research is a posttest-only control group design (Gall, Gall, & Borg, 2003). Hypothesis testing is conducted using multivariate analysis of variance (MANOVA) and a t-test. This analysis measures the effect size of the independent variable on the dependent variable using the formula proposed by Thalheimer & Cook (2002), with the following categories: low ($Es < 0.2$), moderate ($0.2 < Es < 0.8$), and high ($Es > 0.8$). The hypothesis testing procedure involves the following steps: constructing a MANOVA table by calculating JP for treatment, calculating JP for residuals, and computing the total JP (corrected).

The population in this study consists of all primary school teacher education students in Pekanbaru. The total population includes 516 students divided into nine classes. Conducting research involving the entire population would pose certain challenges. Therefore, this study is conducted on selected samples within the population. The selection of classes as research samples is carried out using a random sampling technique. Through this method, two experimental classes and two control classes are chosen. Before determining the samples, an equivalence test is conducted. The validity analysis results for the scientific literacy instrument and learning outcome test items indicate high validity ($1.0 > 0.74$) since CVR-hit > CVR-table with CVR-table = 0.74. Data analysis in this study uses multivariate variance analysis with the help of SPSS 16.0. The assessment of scientific literacy is conducted through scientific literacy questions based on literacy indicators, which include scientific context, scientific knowledge, and scientific competence (Scientific Literacy Assessment Indicators, PISA 2015). This study is carried out over seven sessions, administering 12 scientific literacy questions and evaluating 30 science items. To assess the implementation of learning, an observation sheet is used to evaluate scientific attitudes based on indicators such as interest in science, natural sciences (IPA), and social sciences (IPS), inquiry skills, as well as sensitivity and responsibility in both the experimental and control classes. The lecturers in both the experimental and control classes are science lecturers who have undergone training and socialization on the stages of learning and assessment in STEAM-based learning assisted by Augmented Reality.

RESULT

The results section contains research findings obtained from research data and related to the hypothesis. Descriptive science literacy scores of students in science learning given STEAM learning assisted by Augmented Reality The science literacy scores of students who take science learning with learning using STEAM-based learning based on Augmented Reality with indicators of science literacy questions in the dimensions of science context, science knowledge, and science compatibility. The average science literacy score is obtained through three indicators of science literacy, namely science context, science knowledge, and science competence which produce different scores in the experimental class and the control class.

The average value of the scientific attitude dimension indicators of students who participated in STEAM-based science learning assisted by AR and students who participated in conventional science learning obtained the average value of the scientific attitude dimension of students who participated in learning using STEAM-assisted media based on Augmented Reality. Namely, science interest obtained an average value of 30.06, the science inquiry indicator using scientific methods had an average value of 29.80, and the sensitivity to the environment and responsibility indicator obtained an average value of 28.37. The average value of the scientific attitude dimension of students who participated in learning with conventional learning, namely; science interest obtained an average value of 28.93, the science inquiry indicator using scientific methods had an average value of 28.87, and the sensitivity to the environment and responsibility indicator obtained an average value of 27.99.

The results of the effect size test of the application of Augmented Reality-based STEAM learning on scientific literacy show that the effect size value = 0.5 with a sufficient category. The effect size of 0.5 is the effect size of three dimensions of scientific literacy, scientific context, scientific knowledge, and scientific competence. This shows that the application of Augmented Reality-based STEAM learning is quite effective in improving the dimensions of scientific context, scientific knowledge, and scientific competence in students.

The learning outcomes of science students who received learning through STEAM-based Augmented Reality-assisted learning, and students who followed the conventional approach to the cognitive process of applying conceptual knowledge, and analyzing procedural knowledge.

The average score of science learning achievement of students who participated in AR-based STEAM learning with assistance was at a very good level, and the average score of science learning achievement of students who participated in conventional learning was at a sufficient level.

The results of the effect size test of the application of AR-based learning assisted by STEAM on science learning outcomes showed an Es value = 0.5 so it was classified as sufficient because it was in the category 0.31 <0.8.

Results of the Test of Differences in Science Literacy Scores and Science Learning Achievements of the Experimental and Control Classes Results of the inferential statistical test on the differences in science literacy scores and science learning achievements of students who participated in AR-assisted STEAM-based learning and students who participated in conventional learning.

The results of the general multivariate linear analysis with the SPSS program on the variables of science literacy and science learning achievement showed a significant figure <0.001 with F = 9.471. This means that there is a significant difference in science literacy and science learning

achievement simultaneously between students who take STEAM-based learning assisted by Augmented Reality and students who take conventional learning.

The results of the between-subjects effects test on the differences in Augmented Reality between students who took STEAM-based learning assisted by Augmented Reality and students who took conventional learning showed $F = 18.059$ ($p < 0.05$). Therefore, H0 is rejected, meaning that there is a significant difference in scientific literacy between students who took STEAM-based learning assisted by Augmented Reality and students who took conventional learning. The results of the pairwise comparisons test showed that the difference in the average score of scientific literacy between students who took STEAM-based learning assisted by AR and students who took conventional learning was 2.314. This means that the scientific literacy of students who took STEAM-based learning assisted by Augmented Reality was significantly higher than the scientific literacy of students who took conventional learning.

The results of the between-subjects effects test on the difference in science learning achievement between students who participated in STEAM-based learning assisted by Augmented Reality and students who participated in conventional learning showed $F = 12.953$ ($p < 0.05$). Therefore, H0 is rejected, meaning that there is a significant difference in science learning achievement between students who participated in STEAM-based learning assisted by Augmented Reality and students who participated in conventional learning.

DISCUSSION

The results of the descriptive analysis of students' scientific literacy after science learning through STEAM-based science learning assisted by Augmented Reality showed an increase in the average score and was categorized as very good and good compared to conventional learning. The comparison of the average scores of each dimension of scientific literacy, scientific context, scientific knowledge, and scientific competence had different scores. Based on the average score achieved, the highest score was in the scientific competence aspect. The scientific competence aspect is the ability to use scientific evidence, identify scientific issues, and explain scientific phenomena. These indicators are found in the scientific literacy instrument items, which are closely related to students' scientific knowledge about the human transportation system. The results of this study are in line with research conducted by Hassan et al (2022) which shows that learning through a STEAM-based virtual laboratory can improve scientific literacy in the aspects of context, content, competence, and students' scientific attitudes.

The average value of scientific literacy in the scientific attitude aspect has different values in its indicators. Based on the values obtained, students are more interested in science and curiosity than responsibility and sensitivity to the environment. Scientific literacy is an understanding of science and its application to the needs of society Asyri (2024) Science learning through the STEAM approach based on Augmented Reality shows that classes are more active than science learning through conventional approaches. These results are supported by research by Agussuryani (2022) which emphasizes that a dynamic learning environment through STEAM has a positive impact on students' interest in science.

The results of the between-subjects effect test showed that there was a significant difference in scientific literacy between students who followed the STEAM-based learning approach assisted by Augmented Reality and students who followed the conventional learning approach. The scientific literacy of students who followed the STEAM-based learning approach assisted by Augmented Reality was significantly higher than the scientific literacy of students who followed conventional learning. The results of this study support the research conducted by Augmented Khan et al (2019) that the application of STEAM in learning supports a quality curriculum,

increases interest, and develops teacher professionalism. STEAM contributes to strengthening the pedagogical skills of students as prospective teachers (Carlisle & Weaver, 2019).

The results of this study prove that STEAM-based science learning assisted by Augmented Reality has a positive impact on students' scientific literacy. There is a positive impact of STEAM-based learning assisted by Augmented Reality on students' scientific literacy. STEAM-based learning assisted by Augmented Reality is a learning process that requires students to actively discover concepts through exploration activities using Augmented Reality media. (Asyri et al., 2024).

The results of the hypothesis test on the differences in scientific literacy between students who follow science learning through conventional and Augmented Reality-assisted approaches show that there are significant differences in the achievement of scientific literacy. The scientific literacy of students who follow science learning through conventional and Augmented Reality-assisted approaches is significantly higher than students who follow science learning through conventional approaches.

The results of the descriptive analysis of students' science learning achievement after participating in STEAM-based science learning assisted by Augmented Reality showed an increase in the average score and was categorized as very good and sufficient compared to conventional learning. The results of the between-subjects effects test showed that there was a significant difference in science learning achievement between students who participated in STEAM-based science learning assisted by Augmented Reality and students who participated in science learning in a conventional way. The science learning achievement of students who participated in STEAM-based science learning assisted by Augmented Reality was significantly higher than the science literacy of students who participated in conventional science learning. The results of this study support the research conducted by Griese et al (2020) entitled "Refining Questionnaire-based Assessment of STEAM Students Learning Strategies" which concluded that STEAM-based learning techniques can be used as a pedagogical model for teacher professional development in Elementary Schools. Depending on the individual's learning goals, it is recommended to create a questionnaire for metacognitive tests.

The previous assessment characteristics are separated from learning and are technically irrelevant. The metacognitive latent position becomes clear in the learning strategy and can be measured. Other types of data used are interviews, videography, group discussions, classroom observations, portfolios, and can be used in further research from this study. The findings of this study prove that science learning through STEAM-based learning assisted by Augmented Reality has a positive impact on students' science learning achievement. Furthermore, there is a positive impact of STEAM-based science learning assisted by Augmented Reality on students' science learning achievement. The learning process using STEAM-based learning assisted by Augmented Reality is learning that emphasizes students become active in obtaining concepts through exploration activities using Augmented Reality.

The results of the hypothesis test on the differences in science learning achievement between students who take science learning through STEAM-based learning assisted by Augmented Reality and students who take conventional learning show that there are significant differences in results between the two groups. The science learning achievement of students who take STEAM-based learning assisted by Augmented Reality is significantly higher than the science learning achievement of students who take conventional learning.

The results of this study prove that AR-assisted STEAM-based science learning has a positive impact on science literacy. This positive impact is because the AR-assisted STEAM-based science learning process runs actively, students have a curiosity about concepts, can solve problems,

explain, and argue based on scientific evidence, can utilize technology through the AR media used, and provide reports by interpreting data quantitatively and quantitatively.

Qualitative method. STEAM-based science learning assisted by Augmented Reality is about the problem-solving process in science learning in developing science competencies, science attitudes, and understanding of science concepts.

STEAM-based learning assisted by Augmented Reality can improve students' learning achievement in the cognitive aspects of procedural and knowledge. The process of acquiring a scientific concept involves activities that follow scientific steps or scientific processes. The implementation of Augmented Reality media must follow the predetermined form. The scientific method will encourage students to develop scientific attitudes; interested in science issues, support scientific investigations, and be responsible for environmental resources. The results of this study support research conducted by (Afriana et al., 2016) which concluded that the implementation of PJBL integrated with STEAM can improve science learning achievement and scientific literacy.

Augmented Reality-assisted STEAM-based learning, which has been effectively developed to enhance students' careers, increases interest in science, technology, mathematics, and science (Blotnicky, 2018). As a result, the use of Augmented Reality-assisted STEAM-based science learning can improve students' scientific literacy and science learning achievement.

CONCLUSION

Based on the hypothesis testing, it can be concluded that AR-assisted STEAM-based learning in science learning affects students' science literacy and science learning achievement. The findings are that science literacy results are higher in students who learn through AR-assisted STEAM-based learning than students who learn through conventional methods, learning achievement results are higher in students who learn through AR-assisted STEAM-based learning than students who learn through conventional methods, Paired T-test shows that AR-assisted STEAM-based learning is more sophisticated than conventional learning in improving students' science literacy and learning achievement. The AR-assisted STEAM-based approach in science learning is more advanced than the conventional approach in science learning. The results of this study recommend that alternative learning approaches in science learning in science learning can be implemented through AR-based STEAM-based learning. Before carrying out learning, a tutorial on developing an augmented reality mobile application is first carried out on the material taught according to the learning time. For prospective teachers and lecturers, especially for STEAM-oriented education, they should pay attention to four main things, namely, learning materials and resources, learning activities or activities, learning models and approaches that are collaborated with STEAM, and implementation of evaluation through authentic assessment.

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