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Page xx-xx

Development of Augmented Reality Learning Media for Computer Network Topics in Junior High School

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ABSTRACT

Objective: This study aimed to develop and analyze the effectiveness of Augmented Reality (AR)-based learning media for computer network topics at the junior high school level. The background of this research is based on students' difficulties in understanding abstract computer network concepts when taught using conventional methods. **Method**: The research employed a Research and Development approach using the ADDIE model, which consists of analysis, design, development, implementation, and evaluation stages. AR learning media were developed using paper-based markers that can be scanned via smartphones to display interactive three-dimensional representations of computer network components. **Result**: The research subjects were ninth-grade students and information and communication technology teachers. Data were collected through observations, questionnaires, and learning outcome assessments. The results indicate that the AR-based learning media were validated by material and media experts and were considered practical for classroom implementation. Furthermore, AR media significantly improved students' conceptual understanding and learning engagement compared to conventional instructional methods. **Novelty**: This study introduces innovation through the development of AR learning media that transform abstract concepts of computer networks, which are usually difficult to visualize, into interactive three-dimensional objects that can be directly manipulated by students. Unlike previous research that generally targets higher education or general hardware materials, this study specifically integrates the junior high school informatics curriculum with an ADDIE-based instructional design that emphasizes active engagement and conceptual understanding of students through personal mobile devices.

INTRODUCTION

The development of information and communication technology (ICT) has significantly transformed learning paradigms across various educational levels, including junior high school education (Rayhan et al., 2025). The integration of digital technology in learning no longer functions merely as a supporting tool but has become a primary means of creating interactive, contextual, and student-centered learning environments (Faisal et al., 2025). This transformation requires educators to utilize technology to improve the quality of both learning processes and outcomes (Watrianthos et al., 2022), which is consistent with constructivist learning theory, emphasizing active knowledge construction through interaction, exploration, and contextual learning experiences (Pratami, 2024).

Along with this transformation, the use of digital devices—particularly smartphones—has become an integral part of students' daily lives (Sipaayung, 2025). According to the Ministry of Communication and Digital Affairs of Indonesia, approximately 79.5% of the total population, equivalent to 221 million people, are active Internet users (Komdigi, 2025). Furthermore, Databoks (2025) projected that by 2025, at least 89.2% of Indonesia's population would be active smartphone users. These data indicate a strong potential for utilizing mobile devices as meaningful and relevant

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Page xx-xx

learning media aligned with students' digital characteristics (Yosepha Purparisa, 2020). Mobile learning enables learning to occur anytime and anywhere, providing flexibility and personalization that align with students' learning habits in the digital era (Oktaviane and Herwanto, 2024).

In the educational context, the use of ICT has the potential to promote active and flexible learning while supporting the development of higher order thinking skills (Kurniawan et al., 2024). However, several studies indicate that technology utilization in schools is still dominated by static learning media, such as textbooks and conventional presentations, which have not fully enhanced student engagement and meaningful learning experiences (Aspi et al., 2022). Without interactive and well-designed multimedia learning environments, the potential of ICT to foster higher-order thinking skills cannot be optimally realized (Ali et al., 2025).

This issue is also evident in Informatics learning at the junior high school level, particularly in computer networking topics. Computer network materials involve abstract concepts such as network types, network devices, topologies, and data communication processes that are difficult to understand when delivered through conventional learning media (Azizur & Algirdas, 2023). Limited visualization results in low student engagement, suboptimal conceptual understanding, and poor learning outcomes (Nara Puspitaningrum & Heru Purnomo, 2025). Furthermore, the lack of physical network equipment causes learning activities to be predominantly theoretical and provides minimal contextual learning experiences (Riska and Muis Mappalotteng, 2025). Abstract technical concepts require visual representations to reduce cognitive load and facilitate deeper conceptual understanding, particularly for novice junior high school learners (Rahman et al., 2026).

In line with the implementation of the Merdeka Curriculum, which emphasizes meaningful, participatory learning and conceptual understanding, innovative learning media are needed to bridge abstract concepts into more concrete and comprehensible forms (Rosa et al., 2024; Hadi et al., 2023). One technology with considerable potential to address this challenge is Augmented Reality (AR). Augmented Reality is a technology that enables the real-time integration of virtual objects into real-world environments, allowing learners to interact directly with three-dimensional representations of learning objects (Permatasari et al., 2024). From a pedagogical perspective, Augmented Reality supports experiential and situated learning by allowing students to interact with digital objects embedded in real-world contexts, thereby enhancing engagement and conceptual understanding (Nugraha et al., 2025).

Previous studies have shown that the use of AR in learning can increase student motivation, interest, and conceptual understanding due to more concrete and interactive visualizations than conventional media (Dhimas Mahendra et al., 2025). Muh. Ihsan Zulfikar and Riska (2025) further emphasized that multimarker-based AR learning media can enhance student engagement and promote deep learning by allowing students to actively explore learning concepts from multiple perspectives.

However, existing research on AR-based learning media development for computer network topics has primarily focused on vocational high schools and higher education contexts. Studies specifically addressing AR-based learning media for Informatics learning at the junior high school level and examining feasibility in terms of validity, practicality, and effectiveness remain limited. Additionally, the cognitive characteristics

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Page xx-xx

of junior high school students require adaptive media design aligned with their learning needs and the competency targets of the Merdeka Curriculum (Adzkia, 2025).

The various obstacles students face in understanding arise from the highly abstract nature of the computer network material, which is difficult to visualize using traditional methods. To close this cognitive gap, technological innovations are needed that can interactively connect the physical world and digital information, such as Augmented Reality (AR).

This study aimed to develop learning media for introducing computer networks using Augmented Reality (AR) and to assess the feasibility, practicality, and effectiveness of the media in improving student learning outcomes in informatics subjects for eighth-grade students at SMPN 18 Bulukumba.

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RESEARCH METHOD

This type of research is Research and Development (R&D), and the main focus of this research and development is to design, validate, and test the practicality and effectiveness of an educational technology product, namely a computer network introduction learning media based on Augmented Reality (AR). This research was conducted at SMPN 18 Bulukumba, located in Barugae Village, Bulukumpa District, Bulukumba Regency, South Sulawesi. The subjects of this research were two experts and 24 eighth grade students. The determination of the subjects in this research was based on the formative evaluation stages of Tessmer (1993) and the ADDIE development model, using a purposive sampling technique. To produce learning media that is systematic, measurable, and centered on user needs, the development of this product adapts the ADDIE model. The ADDIE model was chosen because of its comprehensive, logical, and highly relevant framework for developing technology-based learning media. The ADDIE model consists of five stages: analysis, design, development, implementation, and evaluation. The development flow of the ADDIE model applied in this study is shown in Figure 1.

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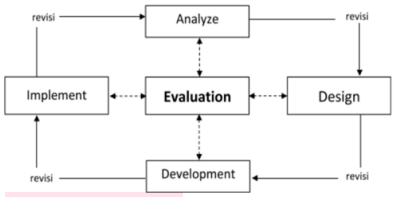

Figure 1. ADDIE Development Model

A. Analysis

Needs analysis was conducted through classroom observations and interviews with an informatics teacher at SMP Negeri 18 Bulukumba, as these methods are commonly used to identify instructional problems and learner needs in educational development research (Nieveen, 2013).

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B. Design

The design stage involved planning the learning media flow, determining the learning materials, developing storyboards, and designing the Augmented Reality (AR) user interface. The developed materials were aligned with the Informatics learning outcomes of the Merdeka Curriculum for eighth-grade students.

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Page xx-xx

C. Development

During the development stage, the AR-based learning media were implemented according to the predetermined design. Three-dimensional models of computer network devices were integrated into the AR application using markers as visual triggers.

D. Implementation

The implementation stage was conducted through limited trials involving eighth-grade students at SMP Negeri 18, Bulukumba. The trials consisted of small- and large-group testing to determine the practicality of the learning media in classroom settings. In addition, learning achievement tests were administered to measure the effectiveness of the learning media used.

E. Evluation

The evaluation stage involved analyzing the results of expert validation, practicality questionnaires, and students' pre- and post-test scores. Media validity was analyzed using Aiken's V, practicality was analyzed using percentage analysis, and effectiveness was measured using N-Gain and paired-sample t-tests.

RESULTS AND DISCUSSION

Results

A. Validity of the Learning Media

Validation of Augmented Reality (AR)-based computer network introduction learning media was conducted to measure technical quality before implementation in learning. Media expert validation was conducted by two media expert validators to assess the feasibility of the developed AR-based learning media. The assessment was conducted on four main aspects: design and appearance, Augmented Reality (AR) visualization, interactivity and navigation, and technical aspects. The assessment results of the two validators are presented in Table 1.

Table 1. Media Validation Results Based on Expert Judgment

Assessment Aspects	Number of Grains	V.1 Score	V.2 Score	Total Score	Maximum Score
Design and Appearance	3	12	11	23	24
Augmented Reality Visualization	3	12	12	24	24
Interactivity and Navigation	3	12	11	23	24
Technical Aspects	2	8	8	16	16
TOTAL	**44**	**42**	**86**	**88**	**97,73**

The level of media validity was calculated using Aiken's V to determine content validity based on expert judgment. In addition, a percentage formula was used to present the validation results in a more interpretable manner.

$$V = \frac{\sum s}{n\,(c-1)}$$

$$P = \frac{86}{88}\,x\,100\% = 97{,}73\%$$

Based on the validation results from media experts, as shown in Table 1, a validity percentage of 97.73% was obtained from the four assessment aspects. Because the value of 97.73% falls within the 81%-100% range, this product is classified as "very valid." This proves that there are no fundamental technical obstacles in the application and that the

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IJORER, Vol. 7, No. 3, May 2026
Page xx-xx

media operate stably. Based on these data findings, it can be confidently concluded that this AR-based learning media is highly suitable for direct testing of research subjects.

B. Practicality of the Learning Media

1. Small-Group Trial

This small group trial aimed to measure the practicality of Augmented Reality (AR)-based computer network introduction learning media when operated directly by end users. This phase involved seven eighth-grade students who were purposively selected to represent the variety of students' academic abilities, namely, low, medium, and high ability categories. This representation is important to ensure that the developed media can be used inclusively by all students at all cognitive levels.

Table 2. Practicality Results of the Learning Media in the Small-Group Trial

Assessment Aspects	Number of Grains	Score Obtained	Maximum Score
Ease of Use	3	74	84
Media Attraction	3	80	84
Benefits of Media	3	78	84
Mean	**9**	**232**	**252**

Based on the results of filling out the student response instrument presented in the table above, the practicality assessment was reviewed from three main aspects with a total of nine assessment items. The ease of use aspect obtained a score of 74 out of a maximum score of 84. This indicates that the interface (UI) and navigation of the AR application are easy to understand and operate independently by students without many technical obstacles. The Attractiveness aspect showed the highest score among the other aspects, namely 80 out of a maximum score of 84. This high score indicates that the 3D visualization of computer network devices through AR technology is very motivating and attracts the visual interest of grade VIII students. Meanwhile, the media benefits aspect obtained a score of 78 out of a maximum score of 84, which means that students felt a direct positive impact from the use of this media on the understanding of the Informatics material being studied. Overall, the accumulated score obtained from the three aspects was 232 out of a total maximum score of 252. Through this calculation, the percentage of the practicality level was 92.06%, using the following formula:

$$P = \frac{232}{252}\, x100 = 92{,}06$$

Referring to the practicality assessment categorization criteria, 92.06% of the data fell into the "Very Practical" category. Based on these detailed data findings, it can be concluded that this AR-based learning media has not only been technically validated by experts but has also proven to be highly practical, easy to use, and engaging for students of various ability levels. Therefore, this medium is highly adequate and ready to be implemented in the trial phase of use on a larger class scale.

2. Large Group Trial

A large-group trial (field trial) was conducted to assess the practicality of Augmented Reality (AR)-based computer network learning media in real classroom settings. This phase involved the participation of 24 eighth-grade students as end users. Practicality was evaluated using a questionnaire instrument that focused on three main aspects: ease of use, media appeal, and media benefits, with a total of nine assessment items, as shown in Table 3.

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IJORER, Vol. 7, No. 3, May 2026
Page xx-xx

Table 3. Practicality Results of the Learning Media in the Large-Group Trial

Assessment Aspects	Number of Grains	Score Obtained	Maximum Score
Ease of Use	3	275	288
Media Attraction	3	275	288
Benefits of Media	3	270	288
Total	**9**	**820**	**864**

Based on the results of the quantitative data analysis presented in the table, students' responses to AR media can be detailed in the user-friendliness aspect, which obtained a score of 275 out of a maximum score of 288. This very high number indicates that the AR application interface is designed intuitively. The Attractiveness aspect obtained a score of 275 out of a maximum score of 288. This score indicates that the integration of AR technology, which can project the form of computer network devices into an interactive 3D form, successfully creates an immersive learning experience and motivates students' visual engagement. The Benefits aspect received a score of 270 out of a maximum score of 288. The high assessment in this aspect proves that students directly feel the positive impact of the AR application in helping them visualize and understand abstract concepts in Informatics subjects, especially in the Computer Networks material.

$$P = \frac{820}{864}\ x\ 100\% = 94{,}91$$

The cumulative score for these three aspects was 820 out of an ideal maximum score of 864. Based on the accumulated data, the average practicality level of the AR learning media was 94.91%. Based on the practicality score interpretation criteria, 94.91% confidently fell into the "Very Practical" category. Based on the detailed findings of this study, it can be concluded that the AR-based learning media development product is not only theoretically valid but also has a very high level of practicality and user acceptance for implementation in the classical learning process.

C. Effectiveness Of The Learning Media

1. N-Gain

An effectiveness test phase was conducted to measure the actual impact of using Augmented Reality (AR) learning media on understanding Computer Networks. This measurement involved 24 eighth-grade students by comparing scores from the pretest before the intervention and the post-test after using AR media.

Based on the analysis of student cognitive improvement data, the total accumulated Normalized Gain (N-Gain) score for all subjects was 16.07. According to the calculation equation used, this total score was divided by the number of participants (N=24), resulting in an average N-Gain of 0.6695, which was then rounded to 0.67.

$$N - Gain\ Average = \frac{16{,}07}{24} = 0{,}6695 \approx 0{,}67$$

An average index of 0.67 proves that interactive visualization through AR applications has a measurable positive impact on student understanding. Referring to Hake's (1998) effectiveness interpretation criteria, 0.67 falls within the moderate (quite effective) range. Therefore, it can be empirically concluded that this AR-based learning medium is effective for implementation as a supporting instrument to improve student learning outcomes in informatics.

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Page xx-xx

2. Paired Sample t-Test

To validate the statistical significance of the improvement in learning outcomes, a parametric analysis was conducted using a Paired Sample T-Test with the assistance of SPSS software version 31.0.1.0. This analysis compared the achievement scores of 24 eighth grade students before (pretest) and after (posttest) the Augmented Reality (AR) media intervention, as shown in Table 4.

Table 4. The Paired Sample T-Test

Variabel	Mean Difference	T	df	Sig. (2-tailed)
Pretest - Posttest	-47.29	-47.423	23	< 0.001

Based on the test data output in Table 4, the mean difference (MED) was -47.29. In absolute terms, this figure indicates a 47.29-point increase in students' average test scores after using AR learning media. Further statistical testing results showed a t-test value of -47.423 with 23 degrees-of-freedom (df). The resulting 2-tailed significance value (Sig. 2-tailed) was <0.001. Given that this probability value is far below the standard significance level limit (<0.05), the null hypothesis was rejected. This conclusively confirms that there is a statistically significant difference in cognitive achievement before and after the implementation of AR-based computer network learning media.

Discussion

The results indicate that the Augmented Reality (AR)-based learning media for computer networking material meets the criteria of validity, practicality, and effectiveness. The high level of validity, with a validity percentage of 97.73% from four assessment aspects (Table 1), indicates that the media is in accordance with the principles of learning design and the characteristics of the abstract nature of computer networking material. This indicates that the developed media is aligned with the learning objectives, subject matter characteristics, and student learning needs, thus ensuring its suitability for instruction (Rahmawati et al., 2021).

The very high level of practicality indicates that the media is easy to use by students and teachers in learning activities, which refers to the criteria for categorizing practicality assessment, with a percentage of 92.06%, as shown in Table 2. The integration of three-dimensional visualization and direct interaction allows students to build a more concrete understanding of abstract computer networks (Fadlilah and Khanifah, 2025).

The use of interactive AR media directly contributes to the effectiveness of learning, as evidenced by a surge in student learning outcomes with an average N-Gain of 0.67 (moderate category) and a significant t-test value ($p < 0.001$). This finding is consistent with previous research reporting that Augmented Reality can improve students' conceptual understanding of computer networking material (Anakotta et al., 2023). In this study, AR-based learning media was implemented at the junior high school level for the topic of computer networking, which is mostly explored in the context of vocational education and higher education (Sadewa & Zakarijah, 2024). This media was designed according to the cognitive characteristics of eighth-grade students and aligned with the learning outcomes of the Merdeka Curriculum, thus supporting a more contextual, meaningful, and student-centered learning experience.

The novelty of this research lies in the introduction of Augmented Reality (AR) learning media innovation that effectively demystifies and transforms the abstract concept of computer networks, which are traditionally difficult to visualize, into

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Page xx-xx

interactive three-dimensional objects that can be directly manipulated by students. Unlike previous research that generally targets higher education or focuses on general hardware, this research specifically integrates the Junior High School Informatics curriculum through ADDIE instructional design. This approach has proven successful in facilitating active engagement and conceptual understanding of students by utilizing their personal mobile devices. Furthermore, the empirical success of this study provides strategic implications for the future direction of educational technology. Because AR has proven highly effective in bridging cognitive acuity in computer network material, this technology opens up great opportunities for its application to other subjects with abstract characteristics at the elementary and secondary education levels. This study's contribution to future education is fundamental, offering a transition from passive, text-based learning to immersive learning environments. To address the limitations of the implementation timeframe of this study, future studies should be designed to expand the pilot to other subjects. A longitudinal study framework specifically evaluating students' knowledge retention levels over a 3- to 6-month post-intervention period is needed to test the hypothesis that visual memory formed by manipulating 3D objects in AR has greater longevity than that formed using conventional 2D media. Furthermore, future research should investigate the impact of skill transfer, namely, the extent to which students' interactions with virtual network (AR) devices directly correlate with their accuracy and efficiency when operating and configuring actual physical network hardware in a computer lab.

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CONCLUSION

Fundamental Finding; This study produced AR learning media that was proven to be highly valid (97.73%) and practical (94.91%) for eighth grade students. Empirically, this 3D visualization significantly improved learning outcomes (N-Gain = 0.67; $p < 0.001$), confirming that AR technology is an effective solution to bridge students' understanding of abstract Computer Network material. **Implications;** The findings suggest that AR-based learning media can serve as an alternative instructional approach for Informatics subjects at the junior high school level. Its implementation has the potential to foster interactive learning environments, enhance student engagement, and support curriculum implementation that prioritizes active participation and conceptual understanding of the subject. This technology also has the potential to create an efficient learning ecosystem by reducing the need for expensive physical laboratory equipment. **Limitation;** Although this Augmented Reality (AR) media intervention demonstrated significant improvements in learning outcomes, this study has several limitations that should be noted. First, the scope of the field trial was limited to a single educational institution with a sole focus on Computer Networking. This may limit the generalizability of the findings if they are applied to populations with different demographic characteristics and school infrastructure. Second, the relatively short duration of the learning implementation in this study did not allow for comprehensive measurements of student memory retention or the impact of AR use on long-term learning outcomes (longitudinal effects). **Future Research:** Based on these limitations, future research should expand the trial scale to a more heterogeneous sample across various schools. Furthermore, longitudinal studies are needed to evaluate the long-term effectiveness and cognitive retention of students. As previously stated, AR technology exploration also

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Page xx-xx

needs to be expanded to other subjects with abstract conceptual characteristics to provide a more comprehensive and innovative contribution to future educational transformation.

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