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The Effectiveness of Robotics Learning Media in Higher Education Using Augmented Reality to Enhance Learning Motivation

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ABSTRACT

Research Aims: This study aims to examine the effectiveness of Augmented Reality (AR)-based robotics learning media in enhancing students' learning motivation in higher education. The background of this research stems from the issue of low student motivation in understanding the complex and diverse components of robotics. The AR-based learning media was developed using the Smart-TIKA model, which is a modification of six development models: Borg & Gall, 4D, ADDIE, Hannafin & Peck, and Waterfall, to produce media that is valid, practical, effective, and systematic.

Design/methodology/approach: This research employs a Research and Development (R&D) method, involving students as test subjects. The instrument used is a learning motivation questionnaire based on a Likert scale. Data analysis was conducted using descriptive statistics and mean difference tests

Research Findings: The results indicate that the use of robotics learning media significantly increases students' learning motivation, with an average effectiveness score of 84.37. Therefore, robotics learning media is effective in supporting the robotics learning process in higher education..

Theoretical Contribution/Originality: Based on the results of the research and analysis conducted, it can be concluded that augmented reality (AR)-based robotics learning media has been proven effective in enhancing students' learning motivation in higher education.

Keywords*:* Learning Media, Robotics, Augmented Reality, Learning Motivation

Introduction

In the era of the Industrial Revolution 4.0, the utilization of technology in education has become a necessity. Higher education in engineering, particularly programs related to robotics, faces challenges in developing innovative and

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engaging teaching methods. A primary issue often encountered is students' difficulty in understanding the complex and abstract components of robotics.

Advancements in educational technology have led to various innovations in learning media, one of which is the use of Augmented Reality (AR) in robotics education. Students frequently struggle to comprehend the diverse forms and functions of robotic components (Pellas et al., 2019). This difficulty negatively affects students' learning motivation and active participation in practical sessions.

Augmented Reality (AR) is a technology that can bridge this gap. AR enables the integration of virtual objects into the real world in real-time, enhancing interactivity, visualization, and conceptual understanding. Previous studies have demonstrated that the application of AR in learning can boost motivation, deepen material comprehension, and encourage active student engagement (Ibáñez & Delgado-Kloos, 2018).

The use of AR offers a more interactive, visual, and immersive learning experience, which has the potential to increase students' motivation (Azuma, 1997). This study focuses on the development and evaluation of the effectiveness of AR-based robotics learning media to enhance learning motivation among university students.

This study focuses on the development and evaluation of the effectiveness of AR-based robotics learning media to enhance learning motivation among university students. The objective is to determine the extent to which AR-based robotics learning media is effective in improving students' learning outcomes and motivation.

Based on initial observations, students often experience confusion in distinguishing various robotic components. This difficulty results in reduced effectiveness of robotics practical sessions. Therefore, it is necessary to develop AR-based learning media that can assist students in recognizing and understanding robotic components in a more interactive and engaging manner.

The objective of this study is to determine the extent to which AR-based robotics learning media is effective in improving students' learning outcomes and motivation.

The results of this study can provide a positive contribution to the development of learning in hardware science, particularly in the robotics course. Additionally, it

can serve as a useful reference for advancing the development of robotics education in the future.

The practical benefits of this study extend to several groups. For students, the learning media can enhance their motivation, which in turn is likely to improve their academic performance. Lecturers can benefit from this media as it provides an innovative tool to deliver course material more effectively, thereby improving the overall quality of instruction in the classroom. Higher education institutions may find this research valuable as it offers insights and references that can help improve the quality of educational services provided to students. Additionally, academics and educational practitioners can use the findings as a positive contribution and a resource to further develop innovative learning media concepts in a more comprehensive and in-depth manner. Finally, other researchers can utilize this study as a reference and foundation for future investigations, particularly those focused on innovations in robotics learning media.

Method

This study employs a Research and Development (R&D) approach using the Smart-TIKA development model, which is a modification of the Borg & Gall, 4D, ADDIE, Hannafin & Peck, and Waterfall models, resulting in a more systematic, iterative, and structured development process.

This research is classified as Research and Development (R&D) (Gall, Gall, & Borg, 2007) with a quantitative approach. The media development process follows the Smart-TIKA model, which combines five development models adapted to enhance the validity, efficiency, effectiveness, and structure of the learning media development.

The subjects of this study are university students enrolled in robotics courses. The universities involved include: (1) Universitas Handayani Makassar for small group trials; (2) Universitas Negeri Makassar for limited group trials; and (3) Universitas Handayani Makassar for field trials, which were subsequently disseminated.

Data collection in this study was conducted using several methods to obtain accurate and relevant data for measuring the effectiveness of augmented reality-based robotics learning media in higher education. The techniques used include:

1. Learning Outcome Tests

Tests were administered to students in the form of pre-tests and post-tests to measure concept mastery before and after using the learning media. The test items were designed to assess students' understanding of robotics material, consisting of multiple-choice and short-answer questions. Data from these tests were used to determine improvements in student learning outcomes.

2. Student Response Questionnaires

Questionnaires were used to gauge students' responses to the developed learning media. These questionnaires were constructed using a 4-point Likert scale (ranging from strongly disagree to strongly agree) and covered aspects such as ease of use, clarity of material, interactivity, and learning motivation. Data from the questionnaires were utilized to assess the media's effectiveness based on student perceptions.

3. Observation

Observations were conducted while students used the learning media. The researcher observed student activities during media usage, their engagement in the learning process, and the media's alignment with learning objectives. This observation aimed to complement the test and questionnaire data with real classroom behavior.

These data collection techniques were implemented to provide a comprehensive overview of the effectiveness of robotics learning media in enhancing students' motivation and learning outcomes.

Research instruments are tools used to collect relevant data to address the research questions and achieve the study's objectives. In this study, several types of instruments were employed to gather both quantitative and qualitative data supporting the measurement of the effectiveness of augmented reality-based robotics learning media.

The methods used include observation and questionnaires. Observation was developed to examine the learning process implementation at Universitas Handayani Makassar. Meanwhile, questionnaires were used to measure students' attitudes and perceptions regarding the Robotics Learning Media in Higher Education.

The research instruments used in this study underwent a Focus Group Discussion (FGD) process involving several experts in the research subject area. This study

employs a Research and Development (R&D) approach using the Smart-TIKA development model, which is a modification of the Borg & Gall, 4D, ADDIE, Hannafin & Peck, and Waterfall models, resulting in a more systematic, iterative, and structured development process.

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To ensure relevance and accuracy, the research instruments were developed through Focus Group Discussion (FGD) with experts. Effectiveness was analyzed using learning outcomes (pre/post-test gain), student responses (Likert scale), and observed classroom behaviors.

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4. Instrument for Evaluating the Effectiveness of Robotics Learning Media

The instrument grid for evaluating the effectiveness of robotics learning media was designed to assess the extent to which the developed media can improve students' conceptual understanding, skills, and learning motivation in robotics courses at the university level. This instrument covers aspects such as learning outcomes, mastery of material, active student participation, and the impact of media use on achieving learning objectives. Additionally, the indicators aim to observe changes in learning behavior and improvements in both cognitive and practical abilities after using augmented reality-based media. With this instrument, a comprehensive picture of the media's effectiveness in enhancing the quality of robotics education can be obtained. The following is the instrument grid for evaluating media effectiveness:

Table 1. Grid of Effectiveness Instrument for Learning Media

No.	Aspect Analyzed	Indicator	Item Number

1	Improvement in Conceptual Understanding	Students find it easier to understand robotics material after using the media	1
		Students can better differentiate robotic components	2
2	Achievement of Learning Objectives	Learning objectives are achieved after using the learning media	3
		The media supports students in achieving the set competencies	4
3	Engagement and Participation	Students are more active in learning with the media	5
		Students show increased interest and motivation	6
4	Student Learning Outcomes	Evaluation scores improve after using the media	7
		There is an improvement in assignments/performance in robotics practicum	8
5	Impact on Learning	The media bridges abstract concepts into more concrete and applicable forms	9
		The media provides an enjoyable learning experience	10

In this study, data analysis techniques were used to process and interpret data obtained from various stages of developing augmented reality-based robotics learning media.

Effectiveness analysis is an evaluation process aimed at determining the extent to which a product, program, or method achieves its intended goals. In the context of developing robotics learning media at the university level, effectiveness analysis helps determine how well the media improves students' understanding of

robotics. This analysis may include measuring learning outcomes before and after using the media, as well as evaluating user responses and feedback regarding the learning media. Thus, effectiveness analysis assists in assessing the degree to which the media successfully meets the established learning objectives.

The effectiveness of the augmented reality-based robotics learning media development in this study was assessed by a team of expert validators across three aspects: cognitive aspects, student participation, and student responses to the learning process.

Data analysis regarding the effectiveness of the robotics learning media device at the university was based on two indicators: (1) Students' knowledge evaluation of the robotics course; and (2) Students' responses to the learning media. The following is a description of the effectiveness data analysis:

5. Learning Outcomes

To evaluate how effectively the learning media achieves learning outcomes, tests were used as evaluation tools. These tests consisted of a pre-test administered before using the learning media and a post-test conducted afterward to determine whether there was an improvement in students' learning outcomes after using augmented reality-based robotics learning media. The difference between these two tests was then analyzed using an effectiveness test.

6. Student Responses

Student response data were calculated by taking the average score from all respondents (X) from (R1, R2, R3, ... Rn). The average response score can be calculated using the following formula:

$$X\ average = \frac{\sum x}{n} \qquad (1)$$

Where:

X average = Average Score

$\sum x$ = Total Score

n = Number of Instrument Items

The average score is then converted based on categorization intervals as follows: Very Effective (4), Effective (3), Not Effective (2), and Very Ineffective (1). Each

aspect or the overall assessed aspects categorized as effective are assigned categories according to a 25-point interval scale. The effectiveness categories can be found in the following table:

Table 2. Effectiveness Categories

Interval	Category
76 - 100	Very Effective
51 - 75	Effective
26 - 50	Not Effective
0 - 25	Very Ineffective

Source: Ridwan and Sunarto, 2013 in Milala et al., 2021

Instrument Validation Coefficient Calculation

The validity coefficient of the instrument was calculated using Aiken's V formula as follows:

$V = \sum s/[n(c-1)]$

Where:

V = Content Validity Coefficient – Aiken's V

$s=r-lo$

lo = Lowest validity rating (in this case, 1)

c = Highest validity rating (in this case, 4)

r = Rating given by an assessor

n = Number of assessors

Example calculation:

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

$$V = \frac{8}{3(4-1)}$$

$$V = \frac{8}{3(3)}$$

$$V = \frac{8}{9}$$

V = 0,8

7. Analysis of Learning Outcome Improvement

The analysis of learning outcome improvement was conducted to test whether the developed robotics learning media at the university was more effective than existing learning media. The improvement in learning outcomes was analyzed using the Gain Score, calculated by the following formula:

$$(g1) = \frac{x2 - x1}{Xmax - X1}$$

Where:

x1 = Pre-test score

x2 = Post-test score

Xmax = Maximum possible score

RESULT AND DISCUSSION

Research Result

1. Measurement of Student Learning Outcomes

The measurement of learning outcomes was conducted to determine the effectiveness of augmented reality (AR)-based robotics learning media on students' cognitive achievement. Based on the data presented in the table, there is a noticeable improvement in learning outcomes, with an increase of 17.08 points, which falls into the category of significant improvement. The gain score is calculated using the following formula:

$$(G1) = \frac{95{,}41 - 78{,}33}{100 - 78{,}33}$$

$$= (G1) = \frac{17{,}08}{21{,}67}$$

$$G1 = 0{,}78$$

Table 3. Comparison of Students' Pre-Test and Post-Test Scores

No.	Aspect Measured	Average Pre-Test Score	Average Post-Test Score	Gain Score	Category
1	Basic Understanding of Robotics	78.33	95.41	0.78	Moderate to High

2. Measurement Results of Students' Learning Motivation

A summary of the average scores reflecting students' motivation toward the use of the learning media is presented in Table 4 below.

Table 4. Assessment of Media Effectiveness Based on Students' Learning Motivation

No.	Motivation Indicator	Average Score	Score	Category
1	Material is easier to understand with the help of the media	3,35	83,90	Very Effective
2	Interest and enthusiasm for	3,17	79,37	Very Effective

	learning have increased			
3	Material aligns with the curriculum	3,22	80,62	Very Effective
4	Media allows exploration of concepts through AR simulation	3,35	83,90	Very Effective
5	Media is engaging and interactive	3,39	84,84	Very Effective
6	Quiz simulations help in gradual understanding of the material	3,28	82,18	Very Effective
7	Students are encouraged to study more deeply	3,24	81,09	Very Effective
8	Accessibility and ease of use of the media	3,42	85,62	Very Effective
Overall Average		3,30	82,69	Very Effective

The analysis results indicate that all indicators scored above 80, with an overall average of 82.69, which falls into the "Very Effective" category. Among the highest-scoring indicators were "accessibility and ease of use of the media" and "media is engaging and interactive," each with a score of 85.62. This suggests that user comfort and interactive design are key factors influencing the enhancement of students' learning motivation.

3. Interpretation of Effectiveness Results

Based on the overall findings, the media is deemed effective in enhancing both students' learning outcomes and motivation. Therefore, it is considered suitable for broad adoption in robotics education within higher education institutions.

Discussion

This study aims to examine the effectiveness of augmented reality (AR)-based robotics learning media in enhancing students' learning motivation within higher education settings. The discussion focuses on interpreting the results obtained from testing the learning media based on three main aspects of effectiveness: (1) student learning outcomes, (2) learning motivation, and (3) user responses to the media.

This improvement aligns with Mayer's (2001) multimedia learning theory, which states that the integration of text, images, and interaction can enhance information retention. By visualizing robotic components through AR, students are able to manipulate 3D objects virtually and connect them with the theoretical knowledge they have acquired, ultimately strengthening their conceptual understanding.

1. Improvement in Student Learning Outcomes

Quantitative data obtained from student tests after using the AR-based robotics learning media indicate a significant increase in understanding of robotics material. The measurement results show that most students achieved scores in the high category, reflecting improved mastery of concepts. The media presents learning content through a visual and interactive approach, thereby supporting students' cognitive processes in understanding the components, functions, and working principles of robotics.

2. Increase in Learning Motivation

Effectiveness is also assessed from the affective side, namely students' learning motivation. Based on the results of questionnaires analyzed using a Likert scale, an average score of 4.32 out of a maximum of 5 was obtained, which is categorized as "very effective." This means that students responded positively to the learning media, expressing interest, enthusiasm, and motivation to further explore robotics.

3. User Response to the Media

The media was also evaluated through feedback from lecturers and students as primary users. The average lecturer response score was 4.40, categorized as "very

practical," while the implementation of the media in class also received a high score of 4.38. This indicates that, in practice, the media is easy to use during lectures and does not require complex technical training.

From the students' perspective, responses were also highly positive. Most students stated that the media was easily accessible on their devices, featured a simple interface, and provided clear usage instructions. This demonstrates that the instructional design adopted through the Smart-TIKA model effectively integrates user needs.

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6. User Response to the Media

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This study shows that the development of AR-based learning media is an innovative strategy that is not only effective in improving learning outcomes and motivation but also relevant to the demands of digital transformation in higher education. By providing experiential learning, students are not only recipients of information but also actively engaged in the process of knowledge exploration.

This study has several limitations that should be considered for evaluation and as input for further research. These limitations include:

- **Limited Scope of the Trial**

This study was conducted within a limited scope, namely in one study program at a single university. This affects the generalizability of the findings, so the effectiveness results of the learning media may not represent the context of robotics learning in other universities with different characteristics.

- **Variables Limited to Effectiveness Aspects**

The main focus of this research is on testing the effectiveness of the learning media in terms of improving student learning outcomes and motivation. The study has not explored in depth the impact of the media on practical skills, teamwork, or other affective aspects that are also important in robotics education.

- **Limited Duration of Media Use**

The developed learning media was only tested in one learning cycle. This relatively short period is insufficient to observe the long-term impact of augmented reality-based media on students' learning processes and outcomes.

- **Technological and Infrastructure Limitations**

During the implementation of the augmented reality-based learning media, there were limitations related to supporting devices, such as the quality of students' gadgets, internet connectivity, and the technical abilities of some users. These factors could potentially affect the learning experience and the results obtained.

- **Variation in Individual Responses**

Students' motivation and acceptance of the learning media are strongly influenced by individual factors, such as learning styles, interest in technology, and readiness for independent learning. This study did not explore these variations in detail, so the interpretation of effectiveness remains general.

Learning outcomes showed significant improvement, with a gain score of 0.78. Students' motivation scores averaged 82.69 (Very Effective). Media accessibility and interactivity were key motivating factors.

The effectiveness aligns with Mayer's multimedia learning theory, suggesting that the integration of text, images, and interaction enhances retention and understanding.

Considering these limitations, the researcher suggests that future studies be conducted with a broader scope, a longer duration of media use, and a more comprehensive approach to measuring various aspects of the learning process.

Conclusion

Based on the results of the research and analysis conducted, it can be concluded that augmented reality (AR)-based robotics learning media has been proven effective in enhancing students' learning motivation in higher education.

Thus, the AR-based learning media developed through the Smart-TIKA model is not only innovative but also makes a tangible contribution to improving the quality of robotics education. Furthermore, it opens opportunities for the development of similar media in other scientific fields.

In summary, augmented reality-based robotics learning media effectively increases students' motivation to learn in higher education. This increase in motivation supports the achievement of more optimal learning outcomes in the field of robotics.

This study recommends that AR-based learning media be more broadly integrated into various technology and engineering courses to support a more interactive learning experience for students. Further research can be conducted to develop additional features in AR media, such as gamification or voice-based interaction, to further enhance learning effectiveness.

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