

Implementation of Augmented Reality-Based Interactive Learning Media To Increase Mathematics Learning Motivation In SMP Negeri 2 Sidoarjo

Nurus Sufairo^{1*}, Sabariah², Suharti³

^{1,2,3}Univeritas PGRI Adi Buana Surabaya, Indonesia

Corresponden author:

E-mail : nurussufairo84@gmail.com

Abstract.

The purpose of this research is to enhance students' motivation to learn mathematics at SMP Negeri 2 Sidoarjo in the eighth grade by creating interactive learning media based on Augmented Reality (AR). This research uses the Research and Development (R&D) method with the ADDIE model, which includes the stages of analysis, design, development, implementation, and evaluation. This learning media is incorporated into the eighth-grade mathematics curriculum and tested by experts to ensure that it is effective and useful in the classroom. Consisting of 36 eighth-grade students, the research subjects were validated by three experts. The learning motivation questionnaire, practicality questionnaire, and observation sheet are the research instruments. The validation results show that the media is very feasible to use, with an average validation score of 92.3%. Additionally, the effectiveness test with pre-test and post-test indicates that the experimental group has higher learning motivation compared to the control group, with a t-test result sig (2-tailed) = 0.000 ($p < 0.05$). This study found that AR-based interactive learning media increases students' desire to learn mathematics and enhances their understanding of concepts. In addition, this media is suitable for use as a technology-based learning innovation in junior high schools.

Keywords: Interactive learning media; Augmented Reality (AR); learning motivation and mathematics.

I. INTRODUCTION

Mathematics is a crucial subject for developing students' logical, analytical, and systematic thinking skills in junior high school. However, research shows that eighth-grade students at SMP Negeri 2 Sidoarjo still have low motivation to learn mathematics. Students often view mathematics as abstract, complicated, and irrelevant to the real world. As a result, many students are passive in the learning process, lack enthusiasm, and struggle to grasp the concepts taught.

Mathematics learning methods dominated by lectures and monotonous practice problems exacerbate the phenomenon of low student motivation to learn mathematics. This method fails to foster student interest and active engagement. This aligns with the research findings of Lubis et al. (2023), which stated that the use of diverse and creative learning media can significantly improve student motivation and learning outcomes. Therefore, learning strategies that motivate students to learn while changing their negative views about mathematics are crucial.

The world of education has seen significant advances in information and communication technology, particularly in the use of interactive digital media for learning. Augmented Reality (AR) technology, which has the ability to blend three-dimensional virtual objects with the real world in real-time and immersively, enables students to have a more contextual and enjoyable learning experience. AR technology also allows abstract concepts to be made more concrete and accessible through mobile devices commonly used by students (Saca, 2021).

Recent studies have shown that using AR-based learning media in mathematics can improve students' motivation, conceptual understanding, and learning interest (Meilindawati, Zainuri, & Hidayah, 2023; Hermawan & Hadi, 2024). AR media also allows students to interact with realistically visualized learning objects, increasing their participation in class. According to research conducted by Sugeng Sungkono, Apiati, and Santika (2022), AR media helps students understand abstract mathematical concepts such as geometry and geometric shapes.

However, most previous research has focused on testing AR applications on a limited scale or on a single topic. No research has systematically developed interactive learning media integrated with the junior high school mathematics curriculum (Indahsari & Sumirat, 2021). Furthermore, the research gap indicates that few studies have developed AR media through comprehensive implementation and expert validation in real classrooms, and empirically analyzed its effects on student learning motivation. Furthermore, AR is typically used solely as a visual aid rather than as part of a comprehensive learning approach.

Eighth-grade students at SMP Negeri 2 Sidoarjo exhibit low motivation to learn mathematics, characterized by a lack of enthusiasm, a passive attitude when speaking in class, and difficulty understanding abstract material. The limited availability of innovative digital learning media in schools, the lack of teacher and student knowledge of technology, and the poor utilization of AR technology in mathematics learning all exacerbate this problem. Based on this situation, the proposed hypothesis is that the development of interactive AR-based learning media can have a significant and positive influence on students' desire to learn mathematics and their understanding of concepts.

Needs analysis, design, development, expert validation, practicality testing, classroom implementation, and effectiveness evaluation are all part of the process of developing AR-based interactive learning media. This research proposes a solution by modifying the Research and Development (R&D) model based on the ADDIE model. The developed media will be integrated into the eighth-grade mathematics curriculum and will include three-dimensional visualization of mathematical materials, interactive features, and instant feedback to increase engagement and appeal.

This study aims to create a valid, practical, and effective AR-based interactive learning media that can increase students' desire to learn mathematics at SMP Negeri 2 Sidoarjo in grade VIII. Furthermore, this study also aims to examine how the use of AR media impacts students' motivation to learn mathematics and their understanding of mathematical concepts compared to conventional learning approaches. The results of this study are expected to contribute to innovations in mathematics learning in junior high schools that use digital technology.

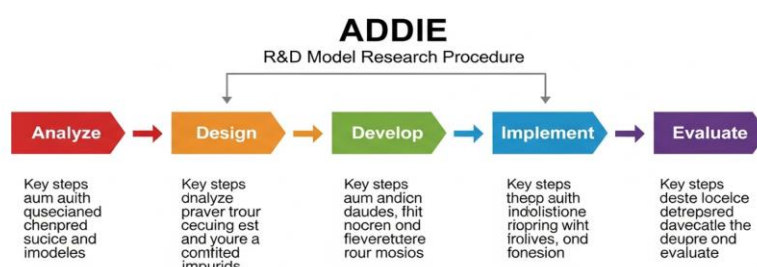
In terms of novelty, this research offers innovation in the creation and implementation of AR-based interactive learning media. This media not only functions as a visual aid but is also integrated with the curriculum and validated by experts. Furthermore, the research and development method in a real classroom tested its efficacy. It is hoped that this research will address the shortcomings of previous research and serve as a reference for the development of interactive digital media for teaching mathematics in Indonesia.

The main objective of this research is to create an AR-based interactive learning media that can increase the learning motivation of eighth-grade students at SMP Negeri 2 Sidoarjo and enhance their understanding of mathematical concepts. Furthermore, this research aims to contribute scientifically to the development of digital learning media in mathematics and provide suggestions for teachers and learning media developers in junior high schools.

II. METHODS

To create and evaluate how effective interactive learning media based on Augmented Reality (AR) is in increasing students' desire to learn mathematics in grade VIII of junior high school, this study uses the Research and Development (R&D) approach together with the ADDIE model, which stands for analysis, design, development, implementation, and evaluation.

Fig. 1. Research procedure



Research design and stages:

This research design includes five operational stages. The first stage is analysis, which identifies the problem of low student interest in learning mathematics and the need for learning media through field observations, teacher interviews, and student surveys. The second stage is curriculum analysis, which determines the core competencies and mathematics materials to be studied in eighth grade, specifically on

geometric shapes. Student characteristics are also analyzed regarding technology readiness and student learning styles.

Developing a blueprint for AR learning media, such as a storyboard, application flowchart, user interface, 3D assets, and AR markers, is part of the design phase. Furthermore, the design of research instruments, such as validation questionnaires, practicality questionnaires, and pre- or post-test motivation questionnaires, is also included.

AR application programming, mathematical content integration, and initial product testing by media and content experts using validation sheets completed the development phase. The product was adjusted based on expert input until it was declared valid.

A limited trial to assess the product's practicality by ten students and an effectiveness test in the eighth grade of SMP Negeri 2 Sidoarjo was part of the implementation phase. The test was conducted on two groups: an experimental group using augmented reality (AR) media and a control group without AR. Learning motivation was measured before and after the test.

Analysis of the practicality and effectiveness of media based on the results of questionnaires, questionnaires, and observations during learning is part of the evaluation process.

Subject, Location, Time, and Research Material:

This trial was conducted in class VIII F at SMP Negeri 2 Sidoarjo, Sidoarjo Regency. The trial involved 36 students from class VIII F of SMP Negeri 2 Sidoarjo, who were selected because they represented the target users of the course material—class VIII students studying algebraic concepts.

Three experts—a learning design expert, a media expert, and a mathematics content expert—tested the validity of an Augmented Reality (AR)-based interactive learning medium in the form of a snakes and ladders board. Meanwhile, a practicality evaluation was obtained from the same experts' assessment to determine whether the developed learning medium was suitable for use in classroom learning.

Research Instruments and Data Collection:

Instruments used include:

- Expert Validation Sheet: used to assess the content, visualization, pedagogy, and technical aspects of AR media using a Likert scale of 1–5. Data were collected through instrument completion by subject matter experts and media experts, and validation was conducted through expert judgment.
- Learning Motivation Questionnaire: Completed by students before and after the intervention to indicate interest, confidence, participation, and enjoyment of learning mathematics. It was validated by educational experts and tested for reliability using Cronbach's Alpha.
- Practicality Questionnaire: Completed by students and teachers to assess the ease of use, comfort, and appeal of the AR media after the trial. Evaluation was conducted by teachers and external reviewers.
- Observation Sheet: Used by teachers and researchers to keep records of technical challenges and student engagement during media implementation.

Data Analysis Techniques:

To evaluate validity and practicality, a percentage formula was used: Results above 81% were categorized as "Very Valid" or "Very Practical". To conduct an effectiveness analysis, a t-test, or independent sample t-test, was used to compare the pre-test and post-test learning motivation scores in the experimental and control groups. Observational data analysis was conducted descriptively-qualitatively and confirmed through data triangulation between questionnaire findings, interviews, and observations. Each step was carried out systematically in accordance with educational development procedures. Each data was represented in standard units and processed using statistical software.

$$P = \frac{\text{Total Skor yang Diperoleh}}{\text{Skor Maksimal Ideal}} \times 100\% \quad (1)$$

III. RESULTS AND DISCUSSION

This research and development resulted in an interactive learning medium based on Augmented Reality. This development was carried out through the ADDIE development process, which consists of five stages.

1. Analysis Stage

Based on the analysis conducted in schools, it was found that teachers primarily use lecture methods during the learning process and rarely use media or technology-related methods. Teachers should design effective and appropriate methods and media to maximize student understanding of the material. Furthermore, teachers must be aware of the limited time and resources available to integrate the material (Sari & Siswono, 2020).

In addition to the factor of the rare use of media or methods related to technology, researchers also analyzed the curriculum and student characteristics so that the learning strategies implemented can be appropriate to the needs and potential of students, so that student learning outcomes are expected to be achieved optimally.

2. Design Stage

At this planning stage, several assessment instruments are needed to determine the suitability of a learning medium that will be used during the learning process, including:

1) The assessment instruments for several validators include learning media expert validators, learning design expert validators, and material expert validators, as well as student response instruments related to learning media in the form of AR (Augmented Reality) snakes and ladders.

2) Product design

At the design stage, this product was developed starting from making the cover, how to play AR snakes and ladders which includes features as an initial understanding for the players, determining the number of players and determining the class the players are taking, markers, materials that have been adjusted according to the class level and other navigation buttons.

3. Development Stage

The final product of this research is a math snakes and ladders application designed to teach eighth-grade math concepts interactively through a smartphone-scannable game. The game displays math problems and snakes and ladders images in a responsive, 3D format.



Fig.2. Cover



Fig. 3. How to Play

Figure 3 shows how to play AR Snakes and Ladders, a classic game using AR. The main goal of the game is to get the number one on the first square. If players successfully pass the ladder, they can move up to a higher square, but if they hit the snake, they will fall to a lower square. Players who can complete the game faster will have a higher score.

This game has several difficulty levels. The easy level is Grade 7, which covers basic operations and fractions; the medium level is Grade 8, which covers algebra and equations; and the hard level is Grade 9, which covers functions and geometry.

Players must answer the questions correctly before they can proceed. Players cannot move if they answer incorrectly, and their opponents have a turn. Therefore, understanding the material and being able to answer correctly are crucial to winning the game.



Fig. 4. Determining the Number of Players and their Class Level

The image shows the initial setup interface (UI) for an app known as Snakes and Ladders AR. This app appears to be an augmented reality (AR) snakes and ladders game with math features.

Before starting the game, users are asked to make several settings on this page. Some of these are Number of Players: Users can choose the number of human players who will participate, for example, two players, namely Player 1 and Player 2. Users fill in the names of each player who will play; and Problem Difficulty: Users can choose the difficulty level of the math problem to be played.

The "START GAME" button is used to begin the game after all settings are complete. The "View Statistics" button is used to view statistics from previous games. This view allows users to customize the game to their needs and desired difficulty level.

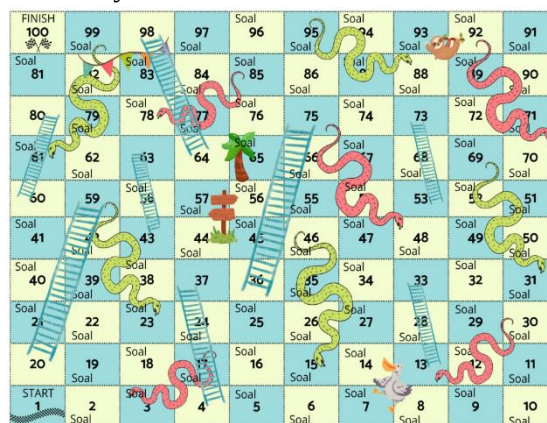


Fig. 5. Snakes and Ladders Marker

In this image, we can see a Snakes and Ladders game board consisting of one hundred squares numbered from one (START) to one hundred (FINISH). This board uses the standard Snakes and Ladders game format, but with some modifications. Numbered Squares: Each square has a sequential number and some squares have the word "Question" written on them. If a player lands on these squares, they are usually asked to answer a question or complete a challenge. Ladders: Smaller numbered squares are connected to larger numbered squares by ladders.

If a player lands at the bottom of a ladder, they can immediately climb onto the square above the ladder, speeding them toward the finish line. Snake: The larger-numbered squares correspond to the smaller-numbered squares in the snake image. If a player lands on the head of the snake, they must climb down to the square at the tail of the snake, thus requiring them to walk backward.

START and FINISH: The game begins at square 1 and ends at square 100. The first player to reach square 100 wins. Generally, the game is played by taking turns rolling the dice, then moving the pieces according to the number on the dice.

Snakes and Ladders is often used as a learning game where users can enter "Problems" into a box with questions or commands related to the subject matter. Conclusion: This educational Snakes and Ladders board game combines elements of entertainment and learning. It's suitable for use in the classroom or as an educational family game.

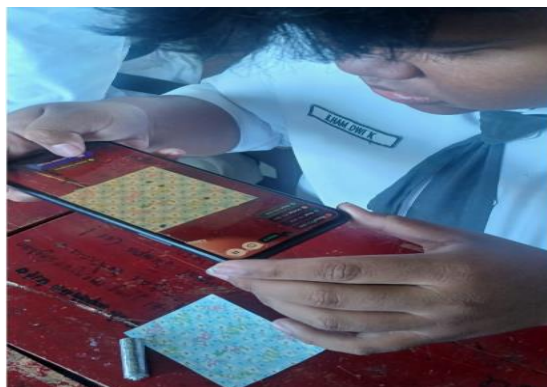


Fig. 6. Smartphone brought close to the Marker

In the image, a student is pointing his smartphone at an AR snakes and ladders marker. The app is intended to scan or detect the code on the AR snakes and ladders marker so it appears on the smartphone screen. This activity can help students learn critical thinking and use digital technology while studying.

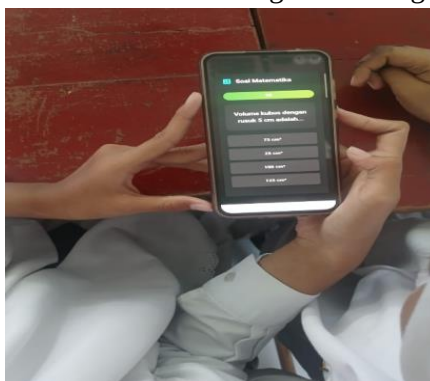


Fig. 7. The question will appear after the Marker is scanned.

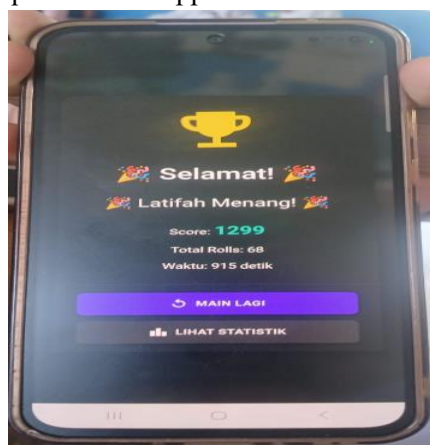


Fig. 8. After finishing playing Snakes and Ladders, the winner will appear along with the score obtained.

4. Implementation Stage

At this stage, the product was piloted on eighth-grade students at SMP Negeri 2 Sidoarjo. After being deemed feasible based on validation results, the product was piloted on these students. The trial was conducted in two stages: in a large class with ten students and in a small class with one teacher.

The purpose of this study was to determine the effectiveness of augmented reality (AR)-based mathematics learning media in teaching students about algebra. Mathematics teachers at SMP Negeri 2 Sidoarjo assessed students' thinking skills for small- and large-class exams.

The practicality of the media is measured by seeing how teachers and students respond to small trials.

Table 2 shows the average AR media practicality score for snakes and ladders.

Respondents	Friday	Max Score	Average Score	Percentage (%)	Kategori
Student	10	40	37.5	93.8	Very Practical
Teacher	1	40	38	95	Very Practical

The results of a small trial show that teachers and students assess the effectiveness of the Augmented Reality (AR)-based snakes and ladders learning media. The extent to which the media is easy to use, understand, and useful in the learning process is crucial for conducting this assessment. The table presented shows that one teacher and ten students were each given a maximum score of 40 points. The results show that the teacher received a score of 38, or 95%, while the students received an average score of 37.5, which is

equivalent to 93.8%. Both scores fall into the "Very Practical" category, meaning the media is very easy to use and implement in learning.

Positive feedback from teachers and students demonstrates that the AR snakes and ladders platform is highly beneficial for the learning process. This platform not only makes the material easier for students to understand but also helps teachers deliver it in an interactive and engaging way. This platform is highly practical, making it worthy of wider use in classroom learning.

5. Evaluation Stage

This stage aims to evaluate the created learning media in terms of quality and suitability for use. This is based on the validation results conducted by media experts, content experts, and education practitioners, as shown in Table 1.

Table 1 shows the expert validity value for AR snake and ladder media.

Rated aspect	Maximum Score	Acquisition Score	Percentage (%)	Category
Content Eligibility	25	23	92	Very Worthy
Display Eligibility	20	18	90	Very Worthy
Technical AR Compliance	20	19	95	Very Worthy
Average			92.3	Very Worthy

The validation results of the snakes and ladders AR media by experts indicate that the media has undergone a thorough evaluation process before being used in learning. During the validation process, media experts, material experts, and education practitioners conducted assessments to ensure the quality and suitability of the media from various important aspects. Content Suitability, Display Suitability, and Technical AR Suitability are the three main elements evaluated, as shown in Table 1. The snakes and ladders AR media received a score of 23 out of a maximum of 25 and is included in the very suitable category, indicating that the material content has met the required suitability standards.

Furthermore, in the Display Suitability section, this media received a score of 18 out of 20, the highest, and a percentage of 90%, which makes it fall into the Very Suitable category. According to this assessment, the media's visual appearance is considered attractive, informative, and suitable for use in the learning process. Technical AR Suitability, the last component, received a score of 19 out of a maximum of 20 points, or 95%, and is categorized as Very Suitable. A high score in this component indicates that the use of AR technology in the snakes and ladders media meets technical requirements and is successful. Overall, the average validation score for the three elements was 92.3%, which is a very suitable score. These results provide confidence that the snakes and ladders AR media is suitable for use as a learning medium because it meets the quality standards for content, display, and technical aspects.

Meanwhile, to determine the effectiveness of media on learning motivation, pre-tests and post-tests were conducted on two groups: the experimental class using AR snakes and ladders media and the control class using conventional learning. The goal was to determine the effectiveness of the media.

Table 3. Average Score of Student Learning Motivation

Group	Pre-test	Post-test	Ascension
Control (n = 36)	71.2	73.5	2.3
Experiment (n = 36)	70.6	86.8	16.2

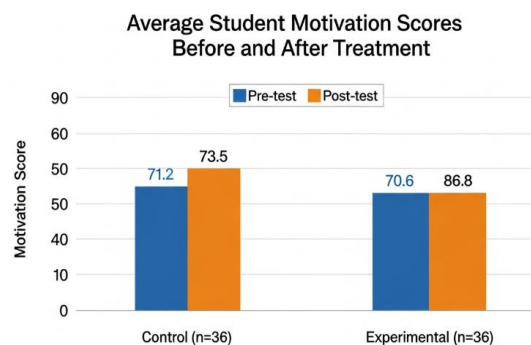


Fig. 9. Average Motivation Increase Diagram

The experimental group achieved significant improvement (16.2 points) compared to the control group (only 2.3 points), as shown in Table 3 and Figure 9.

Table 4. Result of t-Test of Learning Motivation

Variables	Sig (2-tailed)
Learning Motivation (Ex-Con)	0,000

The AR snakes and ladders media has been proven effective in increasing motivation to learn mathematics. The t-test results show that the Sig value (2-tailed) = 0.000 (less than 0.05), indicating a significant difference between the experimental and control groups.

IV. DISCUSSION

a. Relationship between Results and Basic Concepts/Hypotheses

Research shows that interactive augmented reality (AR)-based learning using the snakes and ladders concept can increase students' motivation to learn. This medium not only makes the material visually appealing but also encourages students to actively participate in the learning process. Students become more engaged and motivated to understand the material presented because of this. These results align with the basic idea of constructivist learning theory, which emphasizes the importance of students' active participation in the learning process. Students can gain new knowledge through direct experience and engagement in learning activities through the digital interactions provided by AR media.

This method encourages students to think critically, generate new ideas, and delve deeper into the learning material. The use of AR-based learning media, Snakes and Ladders, also utilizes fun game elements to increase student interest in learning. Students become more motivated, and the learning environment becomes more enjoyable thanks to the combination of new technology and game components. Therefore, this method can help increase student motivation.

b. Key Findings

Ample evidence suggests that snakes and ladders is a valid, useful, and effective tool for teaching mathematics. Trial results show that AR snakes and ladders can present mathematics material in an innovative and easily understood way for students, demonstrating the validity of this medium.

Furthermore, this media practice helps teachers implement technology-based learning in the classroom, making learning more interactive and enjoyable (Sari & Wulandari, 2022). One significant positive effect of using AR snakes and ladders media is an increase in students' desire to learn. Students who most visibly show increased motivation are their enthusiasm for the lesson and their desire to try math problems independently.

The use of snakes and ladders augmented reality (AR) media shows that they have the ability to improve students' understanding of mathematical concepts and foster their curiosity, as well as encourage them to participate in more active and independent mathematics learning activities (Rahmawati et al., 2021). Therefore, it is hoped that the use of AR technology in mathematics learning can be one way to improve the quality of education, especially by increasing students' motivation and their learning outcomes.

c. Factors Causing Results

In mathematics learning, 3D visualization and digital interaction have been shown to improve students' understanding of abstract concepts.

Augmented reality (AR) learning makes the learning experience more interactive and contextual, allowing students to directly manipulate virtual objects, according to (Aini et al., 2022). This aligns with the findings of Pratama and Santoso (2021), who showed that using 3D visual media significantly improved students' comprehension of difficult-to-understand conventional mathematics material.

Furthermore, using a game-based snakes and ladders model in a digital environment makes learning more enjoyable and healthy. According to Rahmawati et al. (2020), gamification in learning can increase student motivation and engagement. Educational games like snakes and ladders can make the learning process more engaging and encourage positive cooperation and competition. Furthermore, the immediate feedback students receive from AR applications enhances their learning experience.

According to a study by Fitriani et al. (2023), real-time feedback features help students improve their understanding and identify errors. According to Nugroho & Wulandari (2021), this type of feedback is crucial for the learning process because it can accelerate the process of reinforcing and correcting concepts.

d. Advantages and Disadvantages of Research

This research has a key advantage in utilizing creative media that is easy to use and suited to the characteristics of digital native students (the generation born after the digital era began). With learning media that is relevant to technological advancements, students adapt more easily and are more interested in actively participating in the learning process.

This media innovation also makes learning more interactive, which makes learning more fun and meaningful for students.

The iterative process of product validation and revision is the focus of this research, in addition to innovation. Before the product is widely used, this procedure ensures that any errors can be corrected. Therefore, the resulting product is guaranteed to be of high quality and suitable for use in the classroom. Furthermore, the use of this media has been shown to significantly increase student engagement and motivation, which are key indicators of learning success.

However, despite several advantages, this research also faces several challenges. One is that the devices cannot be used by all students because some of them do not have smartphones sufficient to support their learning. This inevitably hinders equal access to the newly developed media.

Furthermore, because this research was conducted in just one school and one classroom, the results cannot be generalized to broader situations. Furthermore, there are other limitations that need to be considered, namely the reliance on infrastructure readiness and teachers' digital literacy.

Some schools may lack adequate technological infrastructure or teachers ready to adopt digital-based learning. This can be a barrier to the effective use of innovative media in educational settings.

e. Comparison with Previous Research

This study supports the claims of Sugeng Sungkono et al. (2022) and Riski Meilindawati et al. (2023) that Augmented Reality (AR) media can increase students' interest and understanding of abstract concepts.

Previous studies have found that AR technology can make learning more interactive and engaging for students. However, this study differs from previous studies. The Snakes and Ladders game incorporates game-based learning elements, which is one of the game's distinguishing features.

During the learning process, the integration of game elements aims to increase student engagement and motivation. Furthermore, this study utilized the ADDIE R&D model to conduct systematic validation. This development model provides a more directed structure for the design, development, and evaluation of the AR-based learning media used in the study.

f. Implications, Impacts, and Contributions

This study supports contemporary technology-based learning and constructivist theories. The results support the idea that technology can be used to create more meaningful, enjoyable, and relevant learning

environments tailored to the needs of today's students using interactive, game-based augmented reality (AR) media.

From a practical perspective, this research provides a ready-to-use interactive AR media implementation model for mathematics learning at the junior high school level. This model can be used directly by teachers and educational institutions as an innovative alternative for delivering mathematics material that is often considered abstract and difficult for students to understand. Furthermore, this model can serve as a reference for the development of creative digital media to help students understand mathematics.

The impact of this research is significant, as it paves the way for the adoption of AR technology in the national curriculum. The existence of a proven model makes teacher training on the use of digital media even more important and relevant. Ultimately, this is expected to improve the quality of learning and encourage the adoption of the latest technologies in the Indonesian education system.

V. CONCLUSIONS

Eighth-grade students at SMP Negeri 2 Sidoarjo have found that interactive Augmented Reality (AR)-based learning media increases their motivation and desire to learn mathematics. AR media, such as the Snakes and Ladders game, makes learning more engaging and makes abstract concepts easier to understand. This study recommends further development of AR media, improvements in school technology, research at other levels, and teacher training to help students learn mathematics effectively in the computer and internet era.

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