Adventuring Physics: Integration of Adventure Game and Augmented Reality Based on Android in Physics Learning

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Abstract—One of the physics learning difficulties is the low learning motivation. It is to learn because physics materials are considered to be complex, boring, and abstract for students. Therefore, this research developed an Augmented Reality (AR)-integrated game application "Adventuring Physics" based on android to create more fun physics learning and provide concept visualization on abstract materials so that the students become easier to understand. This study aims to develop a valid and practical application of Adventuring Physics games on physics learning. This research used Research and Development (R&D) design to develop the application. It has two main features: 'play games' and 'augmented reality'. Furthermore, the game's concept in this application is adapted to the physics materials. The AR feature can create visualizations in the form of 3D image projections of the material. The results of the validity assessment show that this application is declared valid, feasible, and reliable. In addition, the results of the practicality assessment showed that it is very practical to be used and worth to be implemented in physics learning. This research has implications as an application of Adventuring Physics that can motivate students to learn physics, and apply digital technology in education, and physics learning.

Keywords—adventuring physics, adventure game, augmented reality

1 Introduction

Physics is a branch of science that examines ideas, rules, concrete, and hypothetical phenomena. Understanding material concepts and using them in practical situations is the essence of physics learning [1]. However, there are many difficulties for students in learning physics. One of these difficulties is the low motivation to learn because the materials are considered as difficult and boring for students. This is supported by [2–5] research which states about the low motivation of students' learning physics subjects. In addition, the results of preliminary studies at SMAN 1 Taman and SMAN 3 Sidoarjo from March-August 2022 in 115 showed that 67.82% or 78 students admitted that they have lack motivation to learn physics. Also, 63.47% or 73 students admitted that learn-

ing physics was boring. Another problem is that there are misconceptions in some physics materials due to the difficulty of visualization, abstract thinking, and complexity, such as in magnetic field subject [6–8]. Supported by preliminary study data, 78.26% or 90 students admitted that it was difficult to understand abstract and microscopic materials because they could not be seen and difficult to visualize.

Responding to this problem, the rapid development of information technology in the world of education is inevitably influenced on educational aspects [9,10]. Educational innovation by utilizing information technology, such as smartphone games will provide a different atmosphere for student appreciation during learning process. Smartphones have been used in schools for various educational purposes, including physics learning [11,12]. Android-based smartphone is a learning tool that can support students in their understanding of learning physics. It is an appropriate learning resources, particularly for current technological advancements [13]. Android-based application is expected to simplify the students receiving and understanding of learning material. On the other hand, it also simplifies the teachers' delivery of learning material.

The android platform can be a physics learning medium that integrates adventure games and Augmented Reality (AR) [14–16]. This is because the concept of an adventure game has a continuous storyline to give its users a high and sustained curiosity [17,18]. Moreover, this game includes game missions and physics problems that must be solved by applying physics concepts. This activity can increase student learning motivation. Meanwhile, AR can visualize into abstract and microscopic objects and also concepts in physics materials well so students can easily understand this game [19–22]. The integration between games and AR is a potential medium to increase students' motivation and enthusiasm for learning physics. Preliminary data also support that 85.21% or 98 students agreed to apply some adventure game to physics learning, and 100 out of 115 (86.96%) students agreed if the game added AR.

Therefore, this research developed an AR-integrated game application, "Adventuring Physics" based on android. It can create more fun physics learning and provide concept visualization on abstract materials so that the students become more accessible to understand the material. This research contributes to innovate an interactive mobile technology in physics learning which leads to positive student learning outcomes. In addition, this research can also help to realize the acceleration of the digitalization on educational field in the "*Merdeka Belajar*" era which is relevant to the Indonesian curriculum and the current development of Information and Communication Technology. This study aims to produce a valid and practical application of Adventuring Physics games.

2 Literature review

2.1 Android-based mobile learning

Android has recently become the operating system of choice for most Indonesian students' smartphones [23]. It is affordable because they can be purchased as a means of communication by almost anyone [24]. Various platforms, such as mobile learning

application, can be installed on the Android system. It is a learning method that provides the opportunities for the students to learn regardless of time or location [25]. Mobile learning has become an applied innovation. Implementation of mobile learning can utilize educational games to facilitate material understanding, increase student thinking power, and increase student interest in learning. Many studies have developed various educational games based on Android, such as for learning English [26], chemistry [27], mathematics [28], computer science [29], coding skills [30], and pharmacy [31], even for inclusive students with visual impairments [32]. More specifically, the use of android-based games is very considerable in learning physics because most students perceive that learning physics is boring and not fun [2], which will be developed in this study.

2.2 Adventure game

According to Culley et al. [33], a program that simulates a small universe and places the player inside of it is called an adventure game. This type of game that emphasizes on the storyline and the player's thinking skills in analyzing places visually or summarizing various events. Integrating adventure games into routine classroom activities is the most common way to be used in education [34]. But until now, there are few studies that still use adventure games in learning. For example, Mulyati et al. [35] who has developed an adventure game on fluid physics material and is declared valid by media and material experts. Lin & Shih [36] have designed and evaluated the effectiveness of a digital game-based adventure education course and got the results that participants have a positive attitude towards this course. An interesting thing related to the use of this type of adventure game is that it can increase the curiosity of players because of the levels that must be completed gradually. Thus, this type of game can attract users to continue playing and has a positive influence if applied in learning.

2.3 Augmented reality

A technology known as augmented reality (AR) combines virtual objects that are either two-dimensional or three-dimensional into a true three-dimensional environment [37]. Then, it instantaneously projects these virtual objects. So, augmented reality can be a useful tool to help users to interact with and perceive the real world. Virtual objects display information that aids users in performing tasks in the real world. AR can be utilized in various functions, one of which is in education and learning that can attract, motivate, and provide real visuals for someone to understand a material concept that requires a high level of reasoning and imagination [38]. Several studies have developed and implemented AR-based media in learning [39–42]. For example, Suprapto et al. [43] conducted an AR-based pocketbook trial on the study of planetary motion physics subject. The results showed the improvement of pretest-posttest scores in students' learning achievement. Based on this study, the researcher recommends to use AR-based media on other abstract physics concepts. Current research will focus on developing AR for physics learning on abstract materials, namely magnetic fields.

2.4 Related works

Research by Dinis *et al.* [44] developed Virtual Reality (VR) and Augmented Reality game-based applications for Civil Engineering Education. The study discussed various interfaces for using gaming environments in engineering education, along with the learning process results. As a preliminary study, it can be said that incorporating VR and AR game-based interfaces made it easier for participants in learning activities to transfer knowledge to one another. Additionally, incorporating VR and AR into games can help promote civil engineering and inspire students while learning.

Research by Trista [45] conducted the interactive and augmented reality games for Indonesian history lessons. The results of this study showed the potential of using augmented reality and game-based learning to support and improve educational experiences nationwide in institutions of higher learning. Furthermore, users of the application will not experience any confusion because it is simple to use and understand.

Research by Boletsis *et al.* [46] developed the gaming project, namely "The Table Mystery", which emphasizes creating a stimulating, enjoyable, and educational environment with a secondary goal of small-scale knowledge transfer. The Table Mystery game study aims to lay the foundation for a more comprehensive investigation into augmented reality educational games. So far, it shows promising potential and has received positive feedback from groups of experts and students who have reviewed and played it.

Research by Hao [47] developed four AR games and investigated their influence on learning in a Grade 5 English course by integrating theories of digital game-based learning, the attention relevance confidence–satisfaction (ARCS) model, and different types of digital games. In this study, students who received instruction using AR games performed better on the post-test than students in the control group, but there was no appreciable difference in learning effectiveness between the two groups. However, there was a significant difference in the four dimensions of ARCS learning motivation between the experimental and control groups.

Another research by Sarifah [48] developed an android-based educational game to increase elementary school students' interest in learning mathematics. The results of this study show that the developed applications can effectively increase students' interest in learning. However, this study still does not explain what type of game to use and not use in AR.

Overall, the review results on related works can be seen in Table 1, which shows the novelty of this study. Based on the table, the differences between this study and previous research are: student-level target is senior high school, physics subjects, android-based digital game media, types of adventure games, and integrated with AR.

Table 1. The difference between current research and related works

Reference	Grade	Subject	Game Media	Game Type	AR
Dinis et al. [44]	University	Civil Engineering	Digital	-	Yes
Trista [45]	Senior High School	History	Digital	-	Yes
Boletsis et al. [46]	Junior High School	Chemistry	Conventional	Adventure	Yes
Hao [47]	Elementary	English	Digital	Role Playing, Quiz, Puzzle, and Matching Games	Yes
Sarifah et al. [48]	Elementary	Math	Digital	-	No
Rizki et al. (This Work)	Senior High School	Physics	Digital	Adventure	Yes

3 Method

3.1 General background

This research used Research and Development (R&D) design to present a development model used as the basis for developing a product to be produced [49]. The basis of this development research is a procedural model that refers to the 4D (Define, Design, Develop, Dissemination) development model which aims to develop and perfect existing products in terms of form and function. The flow of this research stages can be seen in Figure 1.

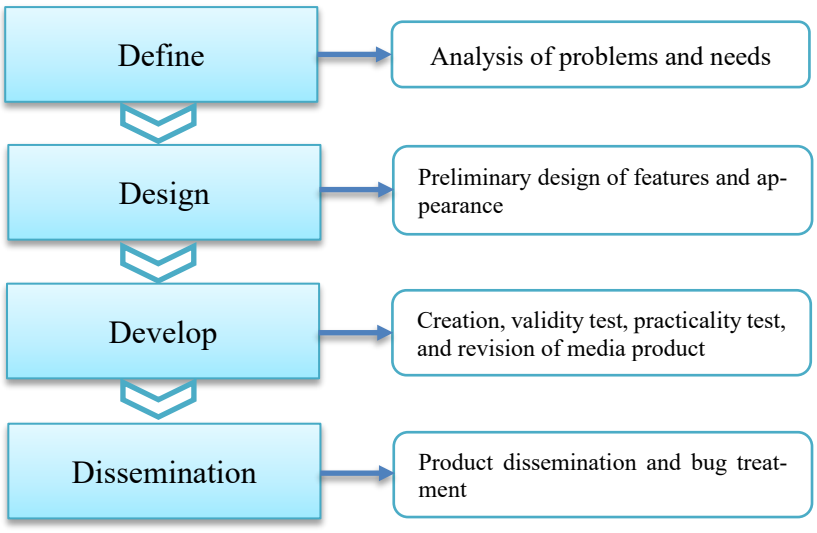

Fig. 1. Research flow and procedures

3.2 Instrument and data collection

This research instrument employed a questionnaire for experts, practitioners, and students using the Likert scale adopted from Nieveen [50]. The questionnaires for experts consists of two parts: a questionnaire to measure the validity of the content and the construct validity. Meanwhile, questionnaires for practitioners and students were used to measure the practicality of the application with indicators: Effective, Interactive, Efficient, and Creativity [51]. Data collection for validity aspects used a questionnaire given to three experts in learning physics, learning media, and educational technology. The goal of the validity test is the content and construct of the application product that has been created. After the product was revised and declared valid, data collection proceeds on the practicality aspect of the application. Data collection was carried out through a questionnaire which was assessed by three practitioners or teachers of physics subjects. In addition, the practicality test also involved 11 students who were selected by simple random sampling.

3.3 Data analysis

Data from the validity assessment results were carried out with descriptive analysis (mean) to determine the criteria for the validity of products and devices that have been developed. In addition, validity result data was used to determine the reliability of products and devices through the Cronbach Alpha (α) value. Products and devices are said to be reliable if the value of $\alpha > 0.6$ [52]. Data from the practicality assessment by teachers and students are also carried out descriptively (mean) to determine the practicality of the Adventuring Physics application product that has been developed. The criteria for determining validity and practicality can be seen in Table 2.

Table 2. Determination of validity and practicality criteria [53]

Validity Criteria		**Practicality Criteria**	
3.25 - 4.00	Very Valid	> 4.00	Very Practical
2.50 - 3.24	Valid	3.00 – 3.99	Practical
1.75 - 2.49	Less Valid	2.00 – 2.99	Quite Practical
1.00 - 1.74	Not Valid	1.00 – 1.99	Not Practical
		< 1.00	Very Not Practical

4 Results and discussion

4.1 Rational development of the Adventuring Physics

The application development of Adventuring Physics is based on several theories, namely the theories of structural gamification, the experience of the cone edgar dale, multi-representation, and constructivism. The theory of structural gamification by Kapp [54] applies the game element to encourage learners without any change in the content of the magnetic field. The content is not transformed into a game but only the structure.

It will be modelled into missions that the player must complete. The main focus of gamifying structure types in Adventuring Physics is to motivate players through content and involve them in the learning process using the 'reward' system.

Edgar Dale's theory related to the cone of experience states that a person's learning outcomes are obtained through direct (concrete) experience, the reality that exists in one's living environment through artificial objects to verbal (abstract) symbols [55,56]. Based on these experiences, the highest level of memory and comprehension (80-90%) will be obtained if students do the role-play, simulate, and work on the real thing [57]. This theory is very supportive in developing the Adventuring Physics application media because it directly involves students in physics learning so that they will better remember the physics concepts included in the game.

The theory of multi representation, according to Izsak and Saherin, states that teaching by involving multi representation provides a rich context for students to understand a concept [58]. This view implies that multi-representation is a way of expressing a concept through various means and forms. In Adventuring Physics applications, multi representations are presented in the form of graphics, visual, verbal, and images, especially in AR which provide the students to learn in various ways depending on the type of intelligence. Multi-representation serves three main purposes in learning: a compliment, limiting interpretation, and building understanding [59].

According to the theory of learning constructivism by Piaget and Vygotsky, the most important principle in educational psychology is that the teacher does not simply give knowledge to students [60]. However, the student must also establish his own knowledge in his mind. Therefore, teachers can provide preliminary information regarding material relevant to Adventuring Physics, after which it can allow students to discover, apply, or develop their own ideas based on that initial information through missions contained in the game application [61].

4.2 Adventuring physics performance

Adventuring Physics app provides several specifications: app size of 125 MB, no internet access required, android version minimum of 7.0 (API 24), making it easy to access by users and compatible or user friendly. To download this application, it can be accessed through the following link: https://play.google.com/store/apps/details?id=com.Asics.AdventuringPhysics. Figure 2 shows the app's home page. This page contains two main features, namely *Play Game* (for playing games) and *Augmented Reality*, as well as two other options, namely *leaderboard* and *setting*. The *leaderboard* aims to provide information on the extent of a player's success rate with each other and be able to compare their abilities with others. This is also an encouragement to players so who are trying to improve their performance so that they are not left behind by other players. Meanwhile, the settings serve to regulate the audio components and about the application.

Fig. 2. App home view

When the user selects the play game feature, then the user will enter the game arena with the concept of strategy that the player must find a way out as soon as possible. Players will be required to create magnetic field-based weapons to fight existing enemies. There are three stages for players to create weapons: designing tools and materials on the item rack, selecting the batteries on the battery rack, and looking for handles. The display of selecting material tools and batteries can be seen in Figure 3. Students' critical thinking skills will be trained when choosing the relevant types of tools, materials, and batteries, accompanied by structured and valid reasons or arguments [62,63]. This is because when the player mistakenly takes an item or battery, the player will lose. The relevant physics concepts in the case of proper battery selection are Ohm's Law and Biot-Savart's Law, as in Equations 1 & 2 [64]. Based on the equations, it can be known that the voltage value is directly proportional to the currents strength, then the it is directly proportional to the magnetic field. So that if the player chooses a relatively small battery voltage, then the magnetic field generated will be small and it cannot attract enemy weapons.

$$V = I \,.\, R \rightarrow V \sim I \tag{1}$$

$$dB = \frac{\mu_0 I \, dl \sin\theta}{4\pi r^2} \rightarrow B \sim I \text{ and } B \sim 1/r^2 \tag{2}$$

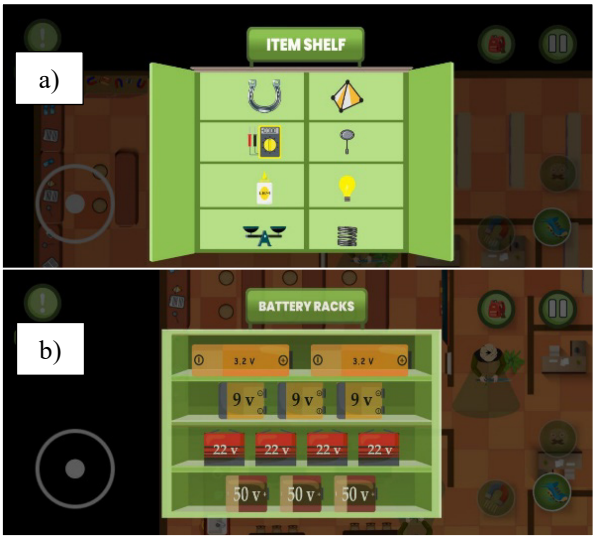

Fig. 3. Display of (a) Item shelf and (b) Battery racks

After the players finish making weapons, they must defeat each enemy by pulling the weapon and knocking it out. When attracting enemy weapons, the concept of Biot-Savart's law still applies to the distance variable. Based on Equation 2, it can be known that the value of the magnetic field is inversely proportional to the square of the distance so that the longer the player's distance from the enemy, the magnetic field weapon cannot attract the enemy's weapon. After the player successfully completes the mission, the time record will be known during the completion of the mission. The group of students who fastest complete the mission, they will be the winners and get rewards from the teacher.

The performance of this application is very suitable to be applied today due to the rapid increase in the use of information and digital technologies in learning, especially in physics [65]. High school students typically use digital games to teach physics [66]. Designing game-based learning media that can organize condition learning situations to create more interesting, challenging, and fun situations can increase student involvement in concept exploration activities. Learning concepts that cannot be practiced in class, providing interactive experiences, strengthening concepts, and evaluating concepts are the important thing for success to teach physics concepts for the students [67]. Supported by an attractive game appearance and easy to use, the theme taken is also interesting so that it can provide a fun learning process for students.

A range of media and teaching methods will increase the enjoyment of learning physics. It will no longer be novel that make boring to students. Students' aptitudes advance with their curiosity, and they are more driven than ever to learn physics [68]. Although the improvement in students' abilities is not immediately apparent, it is expected that the more laid-back learning atmosphere for physics, it will discourage students from procrastinating during class. If it can create enjoyable and comfortable

learning for students, all of the materials taught by complicated and straightforward teachers is much easier to comprehend [69].

Besides the game features, students can access AR features to aid their understanding of complex materials that require visualization assistance, such as the concept of strong current and magnetic fields on a straight wire with electricity (Figure 4). The AR media application works simply; after opening its application, it will appear on the smartphone camera, which can be pointed directly at the supported (pocket)book. The pocketbook can be accessed at the link: https://drive.google.com/file/d/1p5scnaMEHJ0xsXBaRzFvZd6hNqatTss/view?usp=sharing. A marker is then available and the application will detect, causing 3D animated objects to show on the smartphone screen.

This application media is consistent with the '*Merdeka Belajar*' curriculum concept which declares that students need to have skills which are appropriate for the 21st century [70]. This research is supported and in line with the research conducted by [43] that the integration of virtual objects (text, images, and animations) into the real world is made possible by AR. This study results align with the research conducted by [71] which states that the skills in utilizing the internet and computer media both for students and teachers in the learning process are the factors that can affect the level of physics understanding. The literature review looked at the use of AR in education, followed by an overview of some previous studies which used AR applications [72,73].

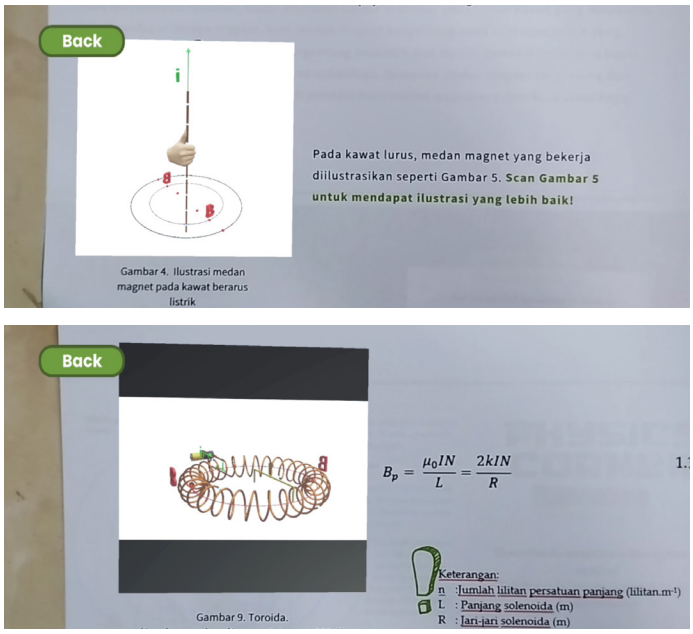

Fig. 4. AR features in the Adventuring Physics app

4.3 Validity assessment

Three experts: physicist learning experts, learning media experts, and educational technology experts, have assessed the application of Adventuring Physics. The assessment focuses on the content and constructs of the application. Content assessment, in general, includes: (1) the suitability of the game's storyline with the achievement of learning, (2) the representation of the application to the students' understanding, (3) the media provides a pleasant learning experience, (4) the suitability of the game's characters and storyline, and (5) the suitability of the application content to basic competencies and competency indicators. Meanwhile, the general construct assessments includes (1) consistency of button layout, (2) ease of starting and ending applications, (3) attractiveness of background colors and designs, (4) level of interactivity, (5) clarity of AR objects and (6) ease of application operations. The results of the validity assessment can be seen in Table 3.

Table 3. Assessment of the Adventuring Physics application validity

Content				**Construct**			
Validity		***Reliability***		***Validity***		***Reliability***	
3,48	Very Valid	0,72	Reliable	3,51	Very Valid	0,94	Reliable

The data from the validity assessment results show that the Adventuring Physics application is declared very valid and reliable, both for content and constructs. This latest application has: (1) integrating adventure games and augmented reality in one application, (2) its application in physics subjects. According to expert validators, this application is declared suitable for use after minor revisions [74]. After corrections were made based on their recommendations, the application of Adventuring Physics was continued with practicality assessment.

4.4 Practicality assessment

The practicality test focuses on Adventuring Physics application products with several indicators: effective, interactive, efficient, and creativity. Three teachers and eleven students carried out the assessment. The results of the assessment of the application's practicality can be seen in Table 4.

Table 4. Results of the Adventuring Physics application practicality test

Practicality Aspects	**Teacher Assessment**		**Student Assessment**	
	Average	***Criteria***	***Average***	***Criteria***
Effective	4,58	Very Practical	4,04	Very Practical
Interactive	4,66	Very Practical	3,93	Practical
Efficient	4,83	Very Practical	4,36	Very Practical
Creativity	4,16	Very Practical	4,22	Very Practical
Average	4,55	Very Practical	4,13	Very Practical

Based on the results of the practicality test, the *Adventuring Physics* application has an average score of 4.55 or is very practical according to the teacher's assessment. While according to the student's assessment, the app has an average score of 4.13 or is very practical. The results of the practicality assessment show that 1) this medium can be used to explain the material; 2) AR projection can appear easily; 3) interactive application which all buttons can be used well and user friendly; 4) flexible and easy to play anywhere; 5) application design can make students interested in learning; 6) can help students actively in learning. In line with research by [75], practical and interactive multimedia-based physics learning can positively influence students' interest in learning and learning outcomes. Games have a positive impact on the education world and have been researched much [76,77].

5 Conclusion

Adventuring Physics is an android-based integrated game application with AR in physics learning. This application has two main features: '*play games*' and '*augmented reality*'. The game's storyline and concept in this application is adapted to the physics materials. The AR feature in this application can create visualizations in the form of 3D image projections of the material. The results of the validity assessment show that this application is declared valid, feasible, and reliable. In addition, the results of the practicality assessment show that this application is very practical both according to teachers and students. Thus, the app is worth applying in physics learning. This research has implications as an application of Adventuring Physics that can motivate students in learning physics, applying digital technology in education, and applied in physics learning. Future research is to be able to apply this application to test its effectiveness in physics learning.

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