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Development of Digital Flashcards Assisted by Augmented Reality on Doppler Effect and Polarization Material

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ABSTRACT

Augmented reality-assisted digital flashcards on doppler effect and polarisation materials that are valid and practical have been successfully developed. This research uses Rowntree's development procedure which consists of three stages: planning stage, development stage and evaluation stage. The evaluation stage in this study uses Tessmer's formative evaluation stage which consists of stages: self evaluation, expert review, one to one evaluation, and small group evaluation. Data collection techniques used walkthroughs and questionnaires. The validity level of this digital flashcard was assessed by three experts, namely material aspect experts, digital flashcard design aspect experts, and augmented reality design aspect experts. The results of the digital flashcard expert validation test at the expert review stage obtained data on the material aspect of 97.75% with a very valid category, the digital flashcard design aspect of 95.75% with a very valid category, and the augmented reality design aspect of 81.5% with a valid category. While the teacher's response was 94.67%, at the one to one evaluation stage an average rating of 86% was obtained in the practical category. At the small group evaluation trial stage, the average assessment result was 87% with a very practical category. Thus, digital flashcards assisted by augmented reality on Doppler effect and polarisation material are declared valid and practical.

1. Introduction

Education is a conscious and systematic effort carried out by people who are entrusted with the responsibility to influence students to have nature and character in accordance with educational ideals [1]. The role of the teacher is very important in the educational process. A teacher must be able to make the learning process fun and interactive so that students will not feel bored, lessons will be more interesting, and students will more easily understand the material presented by the teacher.

A well-planned learning environment can improve the quality of learning and encourage students to demonstrate their understanding of learning activities so that they are given more choices to determine their learning experience [2]. As one of the main components of the learning process, teachers play an important role in creating active, practical, interesting, and meaningful learning for students, so that learning objectives are achieved optimally [3].

Research by [4] found that students are less interested in learning science because of their perception that science is a boring subject that involves too many abstract concepts. Students usually consider science subjects to be abstract, requiring deep understanding and visualization skills [5]. A teacher must be able to choose learning media that will be used to increase students' enthusiasm for learning. The lack of a teacher's role in choosing innovative learning media will affect the limited imagination of learners in reasoning about a problem. [6] stated that, at the university level, many

students have difficulty with three-dimensional or abstract thinking. These difficulties are caused by the misunderstanding of relatively simple concepts and skills [7].

Lack of interest in learning media is also one of the most disturbing learning problems for students, resulting in a lack of motivation in learning activities [8]. Learning media serves as a learning resource for students to obtain messages and information provided by the teacher, so that learning materials can further enhance and shape their knowledge [9]. The use of media in learning can help overcome teachers' limitations in delivering information and limiting lesson hours [10].

Based on observations made by researchers by collecting questionnaires from several students at Public High School OKU Timur, data showed that 46% of students had heard of the use of digital flashcards assisted by augmented reality in learning but had never been applied in the learning process. Eighty% of the students have smartphones, and 20% of them use laptops, tablets, and computers. However. In contrast, 91% of the students were very interested in learning with digital media. According to the data obtained, 94% of the students agreed with the development of digital flashcard learning media assisted by augmented reality. Researchers also conducted interviews with teachers and found that the learning process still uses media in the form of printed books and videos from YouTube, thus making students' understanding of the Doppler Effect and polarization still lacking. Therefore, there is a need for innovative learning media that can increase students' creativity and understanding of the learning materials.

Judging from the description above, the purpose of this research is to develop digital flashcard learning media assisted by augmented reality on the material of the Doppler effect and polarization, which will then be used as one of the learning media. The research method used was Research and Development, with data collection techniques using walkthroughs and questionnaires. The results of data collection were analyzed by collecting all answers obtained from the respondents.

2. Method

The method used in the development of Digital Flashcard Learning Media Assisted with Augmented reality on the Doppler effect and polarization material at Public High School 12 OKU Timur is the Research and Development method. The Rowntree Development Research Model consists of three stages. The first stage was the planning stage, the second stage was the development stage, and the third stage was the evaluation stage. The evaluation uses the Tessmer evaluation model, which consists of four stages: (1) self-evaluation, (2) expert review, (3) one-to-one evaluation, and (4) small group evaluation.

2.1. Planning Stage

The initial stage of the research process involved the development of digital flashcard learning media. This stage begins with conducting a needs analysis. Needs analysis activities are carried out to determine what problems are faced in the field related to the learning Doppler effect and polarization subjects.

2.2. Development Stage

1. Topic Development, At stage, the subject matter is determined. At this stage, researchers compile an outline of the contents of augmented reality-assisted digital flashcards.
2. Draft Preparation, At draft preparation stage was carried out to determine the learning sequence. Determining the format and design of digital flashcards assisted by Augmeted Reality in learning is useful for determining the sequence of learning activities.
3. Prototype Production: In the prototype production stage, the draft was compiled and edited to produce augmented reality-assisted digital flashcards in accordance with planning. The results for all stages of development are called prototype 1.

2.3. Evaluation Stage

At the evaluation stage in this study, using Tessmer's formative evaluation procedure, the evaluation steps were as follows:

1. Self-evaluation is an assessment conducted by the researcher himself and the supervisor of the Digital Flashcards that have been developed. Researchers have reviewed Digital Flashcards by

examining all related aspects, namely the material, language, and design used. At this stage, Prototype 1 was obtained in the form of Digital Flashcards assisted by Augmented reality.

2. Expert Review: At this stage, the designed Digital Flashcards are validated by experts or validators. Validation results were collected using the walktrough technique, and the data obtained were used to determine the validity of the product from the material, language, and design aspects of the Digital Flashcards. The validation results in the form of responses/comments and suggestions listed on the validation sheet were used as a basis for revising the Digital Flashcards (Prototype 1).
3. One-to-one Evaluation: In the one-to-one evaluation stage, three learners in class XI were selected to represent the population. By taking a sample, namely, one learner with high ability, one learner with medium ability, and one learner with low ability. The learners were asked to read and study the materials on the revised Digital Flashcards. Subsequently, the learners were asked to fill out a questionnaire that was given to provide feedback on the Digital Flashcards (prototype 1) used. This study aims to examine the practicality of Digital Flashcards from the point of view of learners as users. The responses of learners in the one-to-one evaluation questionnaire along with suggestions from experts at the expert review stage were used as the basis for revising the Digital Flashcards (Prototype 1) to produce Prototype 2.
4. Small-Group Evaluation: At this stage, prototype 2 was tested on a small group of learners in class XI. The small group consisted of nine learners: three learners with high ability, three learners with medium ability, and three learners with low ability. The learners were asked to read and study the materials on the revised Digital Flashcards. After that, students were asked to fill out a questionnaire that has been given to provide feedback on the Digital Flashcards used. This study aims to examine the practicality of Digital Flashcards from the point of view of students.

2.4. Data collection technique

The data collection technique was used to obtain variable measures. This study used walkthroughs and questionnaires for the data collection.

3. Results and Discussion

Research has been conducted on the development of learning media, namely digital flascard-assisted augmented reality on Doppler effect and polarization material. This study uses the Rowntree and Tessmer evaluation procedures. The following is a description of the results for each stage of this study.

3.1. Results of the Planning Stage

1) Needs Analysis

Based on observations made by researchers by collecting questionnaires from several students at Public High School 12 OKU Timur, data showed that 46% of students had heard of the use of digital flashcards assisted by augmented reality in learning but had never been applied in the learning process. Eighty% of the students have smartphones, and 20% of them use laptops, tablets, and computers. However, 91% of the students were very interested in learning using digital media. According to the data obtained, 94% of the students agreed with the development of digital flashcard learning media assisted by augmented reality. Researchers also conducted interviews with teachers and found that the learning process still uses media in the form of printed books and videos from YouTube, thus making students' understanding of the material Doppler Effect and polarisation is still lacking. Therefore, there is a need for innovative learning media that can increase students' creativity and understanding of the learning materials.

2) Formulation of Learning Objectives

After conducting a needs analysis, the next step was to formulate the learning objectives. The formulation of learning objectives is carried out to determine the competencies that students master after using the developed learning media and to guide the material presented in the learning media so that it does not deviate from predetermined learning outcomes.

Table 1. Formulation of Learning Objectives

Learning Outcomes At the end of phase F, students are expected to be able to apply the concepts and principles of sound waves and light waves in solving problems.	
Learning objectives	Flow of Learning Objectives
Through learning the Doppler effect and polarization, students are able to explain the speed of wave propagation, the Doppler principle and polarization well. Through learning the Doppler effect and polarization, students are expected to be able to differentiate the types and principles of waves well. Through learning the Doppler effect and polarization, students are able to explain the application of sound and light waves around them well. Through studying the Doppler effect and polarization, students are expected to be able to calculate the speed of wave propagation, the frequency of the Doppler effect and the intensity of polarized light correctly.	Explain what wave propagation speed, Doppler principle and polarization are Explain what frequency is Explain the types of waves and wave principles Calculate the speed of wave propagation Analyze the application of the Doppler effect in everyday life Calculate the sound frequency during the dppler effect event Explain what polarization is Explain the relationship between light and waves Analyze the application of polarization in everyday life Calculate the intensity of polarized light

3.2. Development Stage Results

1) Topic Development

In the topic development stage, there is an activity to create a Digital Flashcard Content Outline that aims to determine the learning material according to the topic discussed, in this case, the Doppler effect and polarization.

2) Drafting

The draft is arranged by sorting the material and components presented in the digital flash cards, which are as follows:

1) Digital flashcard cover
2) Instructions for use
3) Learning activities present material descriptions
4) Link and bar code augmented relity
5) Examples of questions and answers to direct students' understanding of the material provided

3.2.3 Prototype Production

The first production, prototype 1, produced augmented reality Digital Flashcards that were adjusted to the draft that had been prepared previously. Standardization in augmented reality Digital Flashcards and display formats is considered so that the presentation of augmented reality Digital Flashcards is attractive to readers. The applications used in this research were Canva, Heyzine Flipbook, and Assembler Edu. Canva is used to design products, Heyzine Flipbook converts designs to digital flashcards, and Assembler Edu is used to design Augmented Reality forms to make displays more attractive.

3.3. Evaluation Phase Results

3.3.1 Self Evaluation

Prototype 1 of Digital Flashcards Assisted with Augmented reality that has been published is then evaluated by researchers with the help of supervisors to assess and re-examine several aspects, namely, content feasibility, language, and ease of use. Prototype 1, which has been considered good by researchers and supervisors, continues to be validated at the expert review stage.

3.3.2 Expert Review

The expert review stage was carried out to determine the validity of Prototype 1 developed by the researchers. At this stage the researchers asked for help from 3 experts, there were 3 components of the validity aspects assessed at this stage, namely material, digital flashcard design and augmented

reality design. An expert validation sheet modified from assessment instruments from several sources was used. Data from the expert review were collected using the walkthrough technique and then analyzed using a Likert scale.

Table 2. Material Validation Results

Indicator	Total score	Maximum score	Score percentage %
Media flashcards	15	15	100%
Contents	24	25	96%
Language	19	20	95%
Appearance	15	15	100%
Material validation results			97,75%((very valid)

Table 3. Digital Flashcard Design Validation Results

Indicator	Total score	Maximum score	Score percentage %
cover design	14	15	93%
content design	34	35	97%
content suitability	20	20	100%
Augmented reality	14	15	93%
***Flashcard* digitalmedia validation results**			95,75% (very valid)

Table 4. Augmented reality design validation results

Indicator	Total score	Maximum score	Score percentage %
Programming	15	20	75%
Visual design	22	25	88%
Augmented reality media validation results			81,50%(Valid)

3.3.3 Teacher Response

After being tested for validity through expert review, prototype 1 was also tested for practicality through a questionnaire administered to the subject teachers. At this stage, the subject teacher response instrument was used to collect data on the use of Prototype 1, which included efficiency, convenience, and attractiveness, with 13 statement items.

Table 5. Subject Teacher Response Questionnaire Assessment Results

Indicator	Total score	Maximum score	Score percentage %
Efficiency	14	15	93%
Convenience	29	30	96%
Attractiveness	19	20	95%
Total			94,67%(Very practical)

3.3.4 One To One Evaluation

After being tested for practicality through a questionnaire given to subject teachers, Prototype 1 was also tested for practicality through the one-to-one evaluation stage because Prototype 1 digital flashcards assisted by augmented reality must be declared valid and practical before being tested at the small group evaluation stage.

Table 6. Results of Student Response Questionnaire Assessment in One-to-one Evaluation Stage

Indicator	Learners			Total score	Maximum score	Score percentage %
	VA	AR	PN			
Usefulness	13	12	12	37	45	82
Convenience	21	22	21	64	75	85
Satisfaction	9	9	9	27	30	90
Average percentage score						86%
Category						Very practical

3.3.5 Small Group Evaluation

After prototype 1 was declared valid and practical through expert review and one-to-one evaluation stages, the researchers revised the prototype based on the suggestions and comments that had been received. The revised prototype 1 is called prototype 2 was then tested on small groups through the small-group evaluation stage to determine its practicality of prototype 2.

Results of Student Response Questionnaires on Small Group Evaluation

Indicator	Learners									Total score	Maximum score	Score percentage %
	NF	GP	IF	BN	EF	CD	IS	MM	EF			
Usefulness	12	11	12	14	13	15	15	14	13	119	135	88%
Convenience	22	21	21	20	20	20	20	22	21	187	225	83%
Satisfaction	8	8	9	9	9	10	10	10	9	82	90	91%
Average percentage score												87%
Category												Very practical

Discussion

This is a type of development research that produces products. The resulting product is in the form of Digital Flashcards with Augmented reality on the Doppler effect and polarization. Digital flashcards can be developed using augmented reality, which is able to connect physics learning with reality, and this study aims to develop a valid and practical product of digital flashcard-assisted augmented reality on Doppler effect and polarization material. This study was conducted in February 2024. The model used in this research combines the Rowntree development model and Tessmer formative evaluation model.

This research was conducted using the Rowntree Model, which is a product-oriented research model. This model was chosen on several grounds: (1) it covers learners, materials, and learning media to achieve set goals; (2) it is procedural and systematic; (3) it provides opportunities to develop evaluation formats to measure components; and (4) it involves experts. The Rowntree model comprises three stages: planning, development, and evaluation. The evaluation stage was carried out according to Tessmer's evaluation procedures, starting from self-evaluation, expert review, one-to-one evaluation, and small-group evaluation to determine the feasibility of augmented reality-assisted digital flashcards developed based on their validity and practicality. The last stage in Tessmer's evaluation, namely the field test, was not carried out because the researchers did not test the effectiveness of the augmented reality-assisted digital flashcards developed. The discussion of each stage in this study is as follows:

1. Planning Stage

The planning stage is carried out by analyzing the needs and formulating the learning objectives. Based on the needs analysis, it is known that the development of digital flashcard learning media assisted by augmented reality on the material of the Doppler effect and polarization needs to be done because:

1) 94.4% of learners also believe that the development of augmented reality-assisted digital flashcards is needed,

2) There are no digital flashcard learning media assisted by augmented reality on the material of the Doppler effect and polarization.
3) All students (100% of respondents) have ICT devices that support access to electronic learning media,
4) Digital flashcards assisted by augmented reality are required because they can contain various materials, images, and 3D animations that help students learn independently. Analysis was also carried out on the basic competencies and core competencies to formulate the learning objectives.

2. Development Stage

Product development is carried out based on an outline of the contents of digital flashcards that have previously been made. The constituent components of augmented reality-assisted digital flashcards are arranged in such a way as to fulfil the characteristics of augmented reality-assisted digital flashcards that are able to teach learners independently. There are 5 components of augmented reality-assisted digital flashcards presented in augmented reality-assisted digital flashcards ranging from covers to practice questions. In the process of making prototypes, researchers have some difficulties in determining the correct design according to the material developed, especially in augmented reality design, owing to the limited components available in assembler edu. In making augmented reality-assisted digital flashcards, researchers use Canva, Heyzine Flip Book web, and assembler edu because they are considered effective and easy to use for readers. The entire stage is carried out systematically to produce a product in the form of augmented reality-assisted digital flashcards on the Doppler effect and polarization Material as prototype-1 (initial product), which has not passed the evaluation stage.

3. Evaluation Stage

The evaluation stage is divided into four stages: 1) self-evaluation, 2) expert review, 3) one-to-one evaluation, and 4) small-group evaluation. These four stages were conducted from January 2024 to February 2024. There were 3 expert panels were involved in the expert review stage, three students of class XI.4 at Public High School 12 OKU Timur in the one-to-one evaluation stage, and nine other students in the small group evaluation stage. The first stage, self-evaluation, was conducted independently by the researcher with the assistance of the thesis supervisor. Prototype 1 that has been revised at this stage will then be validated by experts through expert review. The second stage, namely expert review, was carried out to test the validity of Prototype 1 based on three components: material, digital flashcard design, and augmented reality design. The validation instrument was guided by several research instruments that have been adjusted to develop augmented reality-assisted digital flashcards. This stage involves three panels of experts as validators.

The percentage of the material component was 97.75%, digital flashcard design was 95.75%, augmented reality design was 81.50%, and the average of the three was 91.6%; thus, it included a valid category and was suitable for use in learning.

The third stage was one-to-one evaluation. In addition to being tested for validity through expert review, prototype 1 was also tested for practicality. One-to-one evaluation was conducted at Public High School 12 OKU Timur, involving three students in class XI.4 as research subjects. The students were given a response questionnaire containing several statements related to the practicality of prototype 1. The indicators of practicality in question were usefulness, convenience, and satisfaction. The data obtained were then used to determine the percentage of one-to-one and small-group (HEOS) results based on [11]. Based on the response questionnaire filled out by the students, the overall average result at the one-to-one evaluation stage was 86% with a very practical category. In addition to giving their responses to prototype 1, students also provided comments and suggestions. Comments and suggestions obtained during the expert review and one-to-one evaluation stages were then compiled and used to revise Prototype 1.

A small-group stage was conducted to test the practicality of the developed product. In this case, prototype 2 followed the practicality instrument used in the previous stage. Nine students of class

XI.4 Public High School 12 OKU Timur, were involved at this stage. Based on the response questionnaire filled out by students, the overall average result at the small-group evaluation stage was 87% with a very practical category. Thus, overall, both from the one-to-one evaluation and small group evaluation stages, the augmented reality-assisted digital flashcards developed have very practical criteria by students. This means that augmented reality-assisted digital flashcards are useful, easy to use and provide satisfaction in learning.

4. Conclusion

Based on research on the development of digital flashcards assisted by augmented reality on the material of the Doppler effect and polarization, the following conclusions can be drawn:

1. Digital Flashcards with the help of Augmented Reality on Doppler Effect and Polarization Material have been developed, which are declared valid based on a validity test of the percentage of material components of 97.75%; digital flashcard design was 95.75%, augmented reality design was 81.50%, and the average of the three was 91.6%.
2. Digital Flashcards with the help of Augmented Reality have been developed on Doppler Effect and Polarization Material, which are stated to be practical based on the results of the percentage of practicality, namely 94.67% through the responses of subject teachers, amounting to 86% at the one-to-one evaluation stage and 87% at the small-group evaluation. Thus, the augmented reality-assisted digital flashcards developed in this study are suitable for use in learning as a learning medium for material on the Doppler effect and polarization.

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