Module Equipped with Augmented Reality Technology: An Easy Way to Understand Concepts and Phenomena of Quantum

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Abstract. This research's focus to produce a module equipped with Augmented Reality (AR) technology to display 3D objects for gaining the understanding student of concept and phenomena of quantum. The research used a development method with the Dick and Carey model. The data obtained through questionnaires with a Likert scale for feasibility testing and product trials. A gain value from the results of pre-test and post-test results is used to see the improvement of students' understanding. The research obtained data from feasibility test with a value of 95.9% (aspects of Physics material); 84.2% (aspects of instructional media); and 81.5% (aspects of Physics learning), product trials with a value of 94.3% by teachers and by students get 86.4%, and the results of gain test were 0.213. It shows that product can illustrate abstract concepts into reality with excellent quality and are suitable to use as independent learning materials for students.

Keywords: 3D modeling, Augmented reality, Concepts, Phenomena of quantum, Discovery learning

1 Introduction

Physics is one of the basic sciences [1]. However, Physics is still difficult for students to understand because of several things [2]. Problems in studying Physics have an impact on student learning outcomes. Data on the percentage of students nationally shows that students who answered the National Examination (UN) questions correctly are still below 55% in 2015-2018 [3]. One of the concepts with the lowest percentage is electricity, magnetism and modern physics which reaches 47.39% [3]. One of the causes of the Physics concepts is difficult to understand, which is the difficulty of students to imagine several concepts in Physics that are abstract [4]. This is due to some of the physics material's scope related to the microscopic world (quantum) or the speed of an object that is observed approaching the speed of light [5].

Teaching material capable of visualizing abstract concepts of physics is still lacking. Also, some physics teaching materials still have misconceptions for abstract Physics concepts [6]. Therefore, students need teaching materials or learning media that can visualize the abstract concepts of Physics. Learning media that can be a solution to these problems are a print module that is equipped with Augmented Reality (AR) technology. The module is used because it can make students learn independently and actively [7]. Also, the printed text has advantages compared to digital text [8]. That is because printed teaching materials are the best form to meet the needs for reading processes in the brain related to the eye such as overcoming visual,

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cognitive and metacognitive errors [8]. AR technology as a support in learning media is also considered capable of helping students understand abstract concepts of Physics. This is because AR technology can display 3D objects when scanned by the camera [9]. Some abstract physical concepts can be seen more clearly through simulation assisted by AR technology, such as the Lorentz force [10], electromotive force [11], and radioactive [12] concepts. To prove the potential of a print module equipped with AR technology. Researchers develop a module that is equipped with AR technology on the subject of concepts and phenomena of quantum and test the impact of their use on high school students grade 12th students.

2 Methods

This research and development using one model that is often used in education which is the Dick and Carey research and development model [13]. The stages of research and development on the Dick and Carey model consists of ten steps as in **Figure 1** [13].

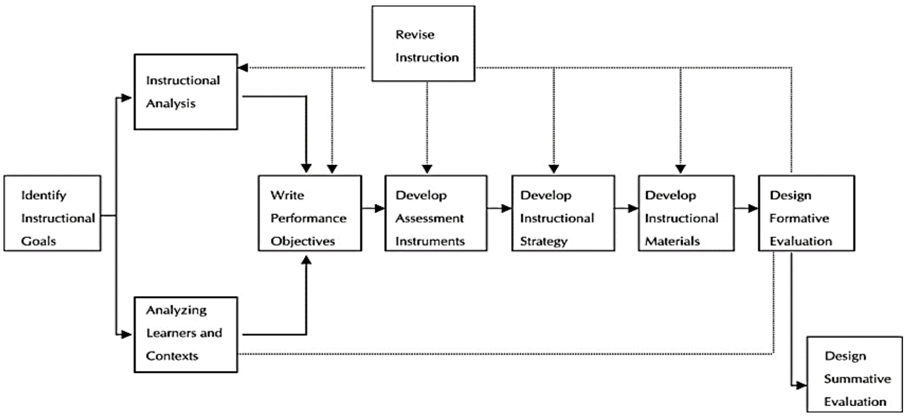


Fig. 1. Schematic of Dick and Carey's research and development model.

This research starts with identifying the purpose of developing a module that is equipped with AR technology and general instructional objectives for the concepts and phenomena of quantum. Also, we analyze the learning model in the module and characteristics of high school students in grade 12th. Based on the results of the analysis, we get a picture of the learning model in the module and some appropriate 3D media. Next, the picture is designed in the form of performance goals that students will do for learning with module and AR application. The formative evaluation component is also designed in the form of a questionnaire with a Likert scale and tests. The design is a reference in the product development process.

At the development stage, we divide into three activities, namely developing (1) assessment instruments for the feasibility test questionnaire, product trials, and tests, (2) learning strategies, and (3) learning materials in modules. The development of module components in this study refers to the eligibility criteria of non-text books made by the Pusat Kurikulum dan Perbukuan (Puskurbuk) and Curriculum 2013 edition 2016 [14]. Also, product development in the form of AR application refers to three main components, namely sensors, processors, and displays [15]. This research uses two ways to collect data, by questionnaire and test. The product that has been developed is tested for eligibility with a questionnaire that refers to the non-text book assessment instrument by Puskurbuk. After the product is deemed feasible by expert lecturers, the module is tested on the user and seen the impact of its use by conducting tests and tested with gain tests.

3 Results and Discussion

3.1 Results of AR Quantum Module and Application Development

The results of developing modules that are equipped with AR technology generally have the same components as other print modules, but some images in the module are equipped with 3D media. The results of the module and application development can be seen in the explanation below.

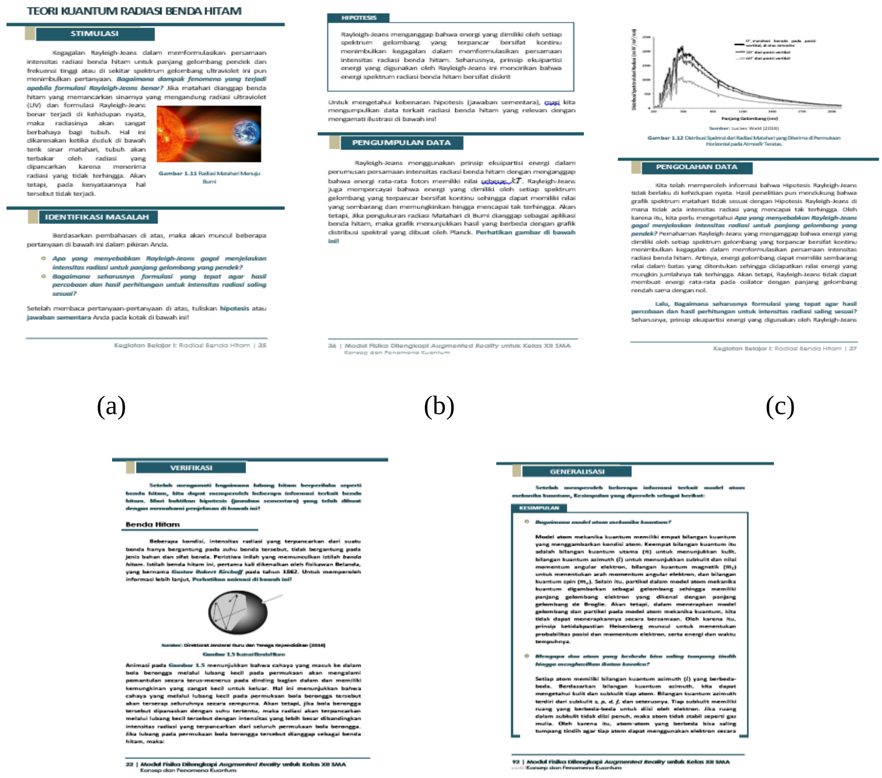
3.1.1 Results of Module Development

Explanation of concepts in the module is divided into three learning activities, namely (1) learning activities I for black body radiation, (2) learning activities II for atoms, and (3) learning activities III for quantum phenomena. Some images in modules that have 3D media will be marked according to the shape of the media displayed. **Figure 2** displays the module that has been developed.

(a) (b)

Fig. 2. (a) Front cover of the module, (b) Front cover of learning activities.

At the core, concepts and phenomena of quantum are packaged in a discovery learning model with six stages, namely stimulation, problem identification, data collection, data processing, verification, and generalization. Display the six stages of the discovery learning model in the module in **Figure 3**.



(a) (b) (c)

(d) (e)

Fig. 3. The six stages of the discovery learning model (a) Stimulation and identification of problems, (b) Data collection, (c) Data processing, (d) Verification, (e) Generalization.

Images in modules that display 3D media will be given the AR logo. The AR logo is divided into two, namely (1) the logo for the image that displays the animation as in **Figure 4.a.**, and (2) the logo for the image that displays the video as in **Figure 4.b**.

(a) (b)

(c) (d)

Fig. 4. (a) Logo for images displaying 3D animation, (b) Logo for images displaying video, (c) Images as markers displaying 3D animation, (d) Images as markers displaying videos.

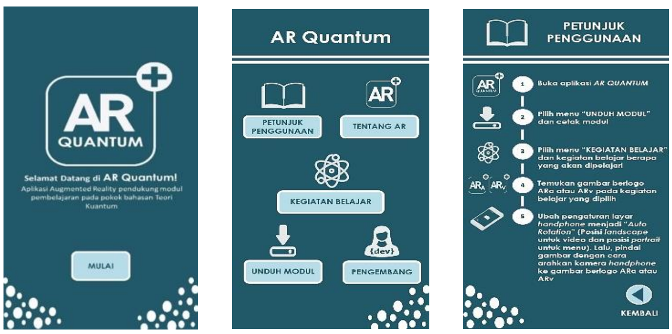
3.1.2 Results of AR Quantum Application Development

The resulting Augmented Reality application is named AR Quantum. This application has as in **Figure 5**. 3D animation display that appears in the application can be seen in **Figure 6**. 3D animation that appears will adjust the position of the camera that scans the marker. Also, the fast or slow 3D media that appears is influenced by the intensity of the light around the marker, the distance of the marker with the scanning camera, and the resolution of the image used as a marker.

In use, 3D media will be displayed quickly if the markers used to obtain ratings above 3 when uploaded on the web Vuforia. Also, the light intensity around the marker must not be too high or too low and do not scan the marker too close.

3.2 Formative Evaluation Results

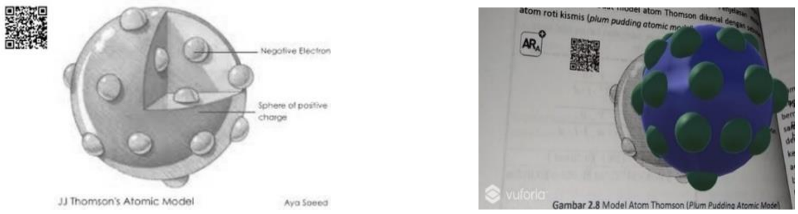
The results of the development of AR modules and applications are evaluated. The evaluation includes a feasibility test, a product trial, and again test from the results of pre-test and post-test.



(a) (b) (c)

(d) (e) (f)

Fig. 5. (a) Appearance display, (b) Main menu, (c) Application usage instructions, (d) Explanation about AR, (e) The development team, (f) Learning activities' menu.



(a) (b)

Fig. 6. (a) Marker, (b) 3D animation in the AR Quantum application.

3.2.1 Feasibility Test Results

The AR module and applications that have been developed are tested for eligibility based on aspects of the concepts, media, and physics learning by expert lecturers. The results of the feasibility test can be seen in Table 1.

Table 1. The results of the product feasibility test by expert lecturers.

No	Aspects Measured	Presentation Scale	Interpretation
Test the feasibility of media learning			
1	Module characteristics	90.0%	Very Good
2	Module components	88.0%	Very Good
3	Size Module	90.0%	Very Good
4	Design front cover of module	74.0%	Good
5	The typography of the front cover	95.0%	Very Good
6	The content layout of module	80.0%	Good

No	Aspects Measured	Presentation Scale	Interpretation
7	Content typography of module	80.0%	Good
8	Illustration of module contents	73.0%	Good
9	AR interface	100.0%	Very Good
10	The functioning of AR media	87.5%	Very Good
Average of all aspects		84.2%	Very Good
No	Aspects Measured	Presentation Scale	Interpretation
Test the feasibility of Physics' concepts			
1	Compatibility of module components with Physics' concepts	95.5%	Very Good
2	Compatibility of Physics' concepts	95.0%	Very Good
3	Language	100.0%	Very Good
Average of all aspects		95.9%	Very Good
No	Aspects Measured	Presentation Scale	Interpretation
Test the feasibility of learning model			
1	Match content with basic competencies	80.0%	Good
2	Characteristics of learning modules	80.0%	Good
3	The stages of discovery learning	82.3%	Very Good
4	Learning assessment	80.0%	Good
Average of all aspects		81.5%	Very Good

During the due diligence, expert lecturers provide suggestions and improvements for several aspects of modules and AR applications. The media expert lecturer suggested that the layout of the elements in the module cover was not appropriate and the image resolution was still low. Therefore, the design aspects of the front cover page and the illustration of the contents of the module get low marks. The expert lecturer in Physics material also provides suggestions for reviewing explanations related to blackbody and adding explanations and schema of the X-ray formation process. The last suggestion given by the Physics learning expert lecturer is to explain the learning theory used in the introduction, maximizing the concept map, and adding question exercises that refer to the indicators. Based on the three results of the feasibility test, the module which is equipped with AR technology is considered to have very good quality to be used as an independent study material.

3.2.2 Product Trial Results

Modules and applications that are already feasible are tested on users. Product trials are conducted by giving products to Physics teachers in SMA Negeri 6 Bekasi and students of class XII IPA 6 at SMA Negeri 1 Bekasi. Teachers and students are given one week to use the product. Teachers and students are given a questionnaire to assess products that have been used for one week. The product trial results can be seen in Table 2.

Table 2. Results of product trials by users.

No	Aspects Measured	Presentation Scale	Interpretation
Product trials by teacher			
1	Material compatibility	94.3%	Very Good
2	Characteristics of the learning module	94.0%	Very Good
3	Language	90.0%	Very Good
4	AR application	97.2%	Very Good
Average of all aspects		94.3%	Very Good
No	Aspects Measured	Presentation Scale	Interpretation
Product trials by students			
1	Display module	85.8%	Very Good
2	Exposure to material in the module	86.2%	Very Good
3	Language	87.5%	Very Good
4	AR application	86.8%	Very Good
Average of all aspects		86.4%	Very Good

The results of product trials by teachers and students scored above 81%. This shows that teachers and students consider that modules equipped with AR technology are appropriate to be used as independent learning materials for students.

3.2.3 Gain Test Results

In addition to obtaining data through questionnaires, this study also used tests. The test is in the form of a pre-test before students use the product and post-test after use module and application for one week. This test is conducted by students of class XII IPA 6 at SMA Negeri 1 Bekasi in August 2019. The results of the pre-test and post-test will be tested with the again test. The N-gain value will indicate differences in students' understanding of Physics material before and after using a module that is equipped with AR technology. N-gain by 25 of students is 0.213 with pre-test average 18.14 and post-test average 35.57.

The gain test results indicate that the difference in understanding is in a low category. One of the reasons for the lack of increased understanding is the time of the pre-test and post-test. This test is carried out before the material in the module is taught by the teacher in class and its implementation at the last hour is considered to affect the performance of students. This was also written by students in the product trial questionnaire. Students write that AR is a good medium to be applied in learning Physics and helps to understand new concepts. The use of AR can increase student motivation. However, the module as an independent learning material is not quite by the learning model of students. Students still need the teacher as a facilitator to explain the material that is difficult to understand.

4 Conclusion

Some expert lecturers have tested the feasibility of modules equipped with AR technology for the subject of concepts and phenomena of quantum. The results of the feasibility test obtained a very good category for this product with a value of 95.9% (aspects of Physics' concepts), 84.2% (aspects of learning media), and 81.5% (aspects of learning model). After being tested for eligibility, this product was tested on teachers and students with a value of 94.3% and 86.4%. Based on the results of the assessment, this product is considered to have very good quality, helps understand abstract concepts, and it is suitable for use as independent learning materials for students. However, the process of using it must be facilitated by the teacher to gain a more significant increase in understanding.

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