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Arduino-Based High-Frequency Signal Data Acquisition for Learning Media on Antenna and Wave Propagation Practices

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ABSTRACT

This paper discusses the research results on the development of learning media and the results of the feasibility test for the learning process. This study aims to: (1) obtain the design and prototype of Arduino-based high-frequency signal data acquisition learning media; (2) find out the level of feasibility of learning media that has been made for the learning process of Antenna Practice and Wave Propagation courses. The research model uses Research and Development with the ADDIE development method. The research stages in the ADDIE method are Analyze, Design, Develop, Implement, and Evaluate. The research began with the development of learning media called Antenna Pattern Radiation Learning Media and the Practicum Module containing a collection of lab sheets for practicum activities using the media. The next step involves assessing the viability of the media. Validation tests gather expert feedback on materials, media, and users. In this study, data was collected using a questionnaire and analyzed quantitatively using descriptive analysis techniques. This research and development effort led to the creation of Antenna Pattern Radiation Learning Media and its practical modules. The test results showed that the material experts gave it a score of 95%, media experts rated it at 85.4%, and users (students) gave it a score of 80.65%. Based on the evaluations of the material experts, media experts, and users, it can be concluded that the Antenna Pattern Radiation learning media falls into the highly feasible category and can be utilized as a learning resource in courses related to Antenna and Wave Propagation.

Keywords*:* antenna, Arduino, AD8307, ADDIE, radiation patterns, wave propagation, instructional media.

INTRODUCTION

Currently, telecommunication technology is more directed toward wireless communication because this technology is more profitable than wired communication [1]. Wireless communication or radio communication uses a component called an antenna, both at the transmitter and receiver.

An Antenna is one of the important components in radio communication. This transmitting antenna functions to emit electromagnetic waves into the air, while the receiving antenna functions to capture electromagnetic wave radiation from in the air[2].

The characteristics of the antenna are very important in wireless communication because the characteristics of the antenna can affect the distance and direction of the emission of electromagnetic waves sent by the radio transmitter to the radio receiver [3]. If the characteristics of the antenna are not good, then the function of the antenna cannot work perfectly, and then the communication process cannot work properly either.

The Electronics and Informatics Engineering Education Department is a vocational department that prepares graduates to be ready to face technological developments and the world of work. The learning process for each subject in this department requires various visual aids and practical tools to carry out the theoretical and practical lecture processes. Complete and varied teaching aids are expected to produce graduate competencies that align with the demands of the world of work [4].

Learning media is needed to understand concepts when attending theoretical and practical lectures. Sanaky [5] states that learning media in the learning process is used as a tool

that functions to convey material and provide stimulation in learning.

In addition, learning media is also useful for (1) clarifying in presenting messages or material so that they are not only in the form of verbal messages; (2) can overcome the limitations of space, time, and sensory power; (3) presenting appropriate and diverse media can overcome the nature of students who tend to be silent; (4) makes it easier for teachers to deal with the different nature and conditions of students who are required the same for each student by the curriculum and educational materials [6].

One of the courses in the curriculum of the Department of Electronics Engineering Education is the Antenna and Wave Propagation Course. One of the syllabi for this course discusses Maxwell's equations, the characteristics of electromagnetic waves, the spectrum of electromagnetic waves, and the various types of antennas and their characteristics.

Lecture material is delivered through theoretical learning activities in the classroom and practical learning in the laboratory. One of the theoretical and practical materials is studying the various types of antennas along with the characteristics of the electromagnetic waves emitted by the antenna. So far, antenna practice activities have only been limited to measuring the value of the Voltage Standing Wave Ratio (VSWR) due to the limited measuring tools available in the Telecommunications laboratory. Observing electromagnetic wave radiation patterns could not be carried out because the laboratory still needed the equipment to measure Antenna Radiation Patterns. It is feared that this will reduce the freedom of students and lecturers to disclose lecture material that is delivered in-depth and quickly [7]. Therefore, the development of practicum learning media along with practice guidelines is needed to optimize the resulting learning impact [8].

The media that is often used in Antenna and Wave Propagation courses is currently still limited to using PowerPoint highlights. PowerPoint media is a media commonly used by most teachers. This power point was chosen only based on habits in using media without regard to choosing the right media according to the material and student characteristics. The selection of PowerPoint for learning media rarely pays attention to the theory of selecting learning media and is only based on habit [9].

The success of the learning process is strongly influenced by internal and external factors. One of the external factors that are very influential in achieving learning objectives is the motivation of the teacher in carrying out his duties, the creativity of the teacher, the competency of the teacher, and laboratory facilities. Taken together, these external factors have a very large influence on student learning outcomes, with a correlation of $r = 0.564$ [10].

Therefore, this study aims to produce a learning media in the form of a measuring instrument that can display the radiation pattern of an antenna. This learning media will be used in the learning process of Antenna and Wave Propagation courses. This tool is expected to be able to integrate material using a variety of active learning strategies to help students connect what they already know with actual real conditions[11].

The resulting media is in the form of trainers and companion modules. A trainer is a set of laboratory equipment that is used as a learning medium and is equipped with a module containing trainer operating instructions and a set of lab sheets containing material, assignments, tests, and evaluations [12].

Several studies on the measurement of antenna radiation patterns have been carried out by several other researchers before. Fadlilah [13] reports how to create software that can be used to simulate the radiation pattern of an antenna. Chirag Gupta [14] revealed the radiation pattern in 3D estimation using MATLAB. Nomas [15] developed a radiation pattern measuring instrument consisting of a mechanical system and software to display the results of antenna radiation pattern measurements. Andi Sri Irtawaty [16] researched the influence of the

performance of an antenna, and one of the influences is the antenna radiation pattern.

Nazurah Hamzah and Syarfa Zahirah Sapuan [17] have also succeeded in developing a tool to show real antenna radiation patterns. The following are the results of the development of this research:

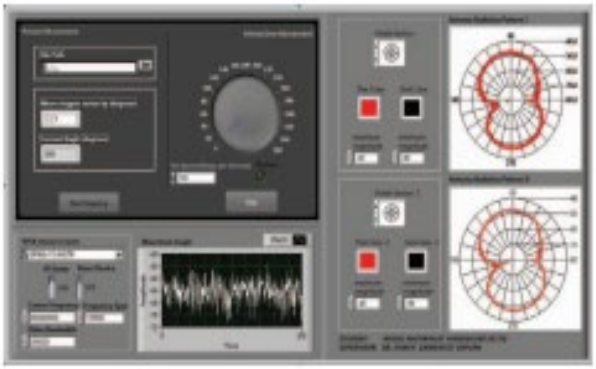
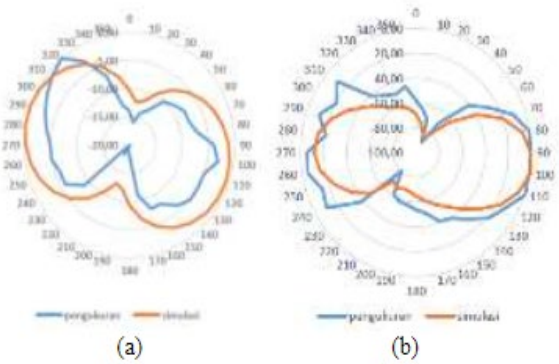


Figure 1. GUI of LabVIEW-based software[17].

Research conducted by Nazurah Hamzah [17] has been able to display antenna radiation patterns in real terms but has limitations in that there are no learning modules when it is to be used as learning media.

Research that describes antenna radiation patterns has also been studied by Tanzila Azizi Rochim [18]. This study measures the V-Vertical Ground Plane antenna, which can operate in the VHF and UHF bands. Tests were conducted on the antenna to determine the parameters, including the radiation pattern. Measurement of the radiation pattern by making a circular pattern with angle markers from 0^o to 360^o with increments of 10o each which is described in Figure 2.



(a) (b)

Figure 2. The azimuth radiation pattern of the V-Vertical ground-plane antenna
(a) VHF (b) UHF [18]

Research conducted by Azizi Rochim[18] has been able to display real antenna radiation patterns and can compare them with simulations. However, this research has limitations because the measurement of radiation patterns has a range of 10^o in its measurement, and there is no learning module when used as a learning medium.

Some of the studies mentioned above show that it is possible to realize a measuring instrument that can display the antenna radiation pattern on a computer screen. It's just that some of these studies have yet to discuss its use for learning media. All of the above descriptions have encouraged this research to take up the topic of how to develop learning media to measure radiation patterns. This learning media is used for practical activities in Antenna and Wave Propagation courses. With this learning media, it is hoped to increase understanding of material about antennas and propagation. This research is entitled "High-Frequency Signal Data Acquisition Using Arduino for Learning Media for Antenna Systems and Wave Propagation".

The antenna radiation pattern measuring instrument that will be made functions to display the antenna radiation pattern by acquiring high-frequency signal data. This tool is useful for proving the radiation pattern of an antenna so that it can be compared between the calculated radiation pattern and the measured radiation pattern. It is hoped that students will better understand the concept of the radiation pattern of an antenna.

This research was carried out using Research Group Telecommunication and Digital Networking funds at the Department of Electronics and Informatics Engineering, Faculty of Engineering, Universitas Negeri Yogyakarta, especially for the cost of procuring hardware components for system development. As for the design of both hardware and software, it is done together with students as research for the thesis final project. Data collection was fully carried out by students who were working on the

final thesis assignment. This paper is one of the research outputs of the Research Group.

METHODS

The method used in developing Arduino-based Antenna Pattern Radiation learning media is a research and development (R&D) method. The development of learning media in this study uses a quantitative descriptive approach. The learning media development model used in this study uses the ADDIE concept (Analysis, Design, Development, Implementation, and Evaluation)[19]. This development model was chosen because it is suitable and simple when developing learning media. Here is a picture of the procedure from ADDIE development:

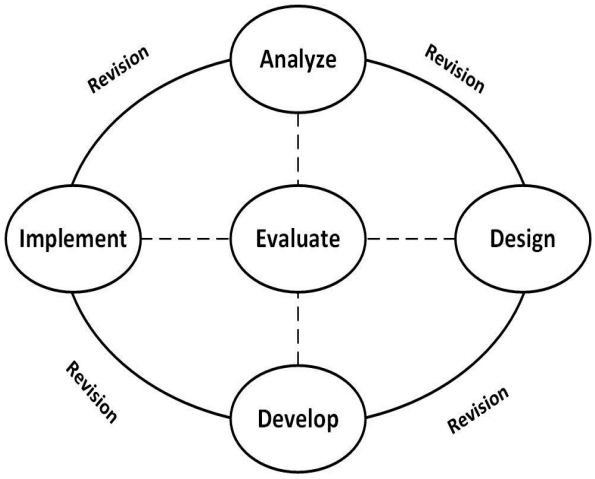


Figure 3. ADDIE development procedure [19]

A. Research Target

The subjects in this study were lecturers as experts and students as users. The subject of this research provides validation of the research object produced in this development research. Lecturers as research subjects act as material experts and media experts in charge of validating the learning media created in this study. While students are also research subjects as users of learning media developed in this study. The research object is learning media produced in the form of an Arduino-based high-frequency signal data acquisition tool consisting of tools and applications as learning modules.

B. Procedure

The initial procedure carried out in this study was to identify potential problems in the Antenna and Wave Propagation practical courses in the Electronic Engineering Education Study Program, Faculty of Engineering, UNY. Based on the results of observations that have been made, this course does not yet have appropriate learning media, especially in explaining antenna radiation patterns. Based on these problems, we need a tool that can present the radiation pattern of an antenna.

The second stage of this research was to design a product for an Arduino-based high-frequency signal data acquisition device. The design stages carried out were: (1) designing the electronic circuit and the box; (2) designing software; and (3) designing learning modules. After the needs analysis has been completed, the process of designing tools to be used as learning media is carried out. The media design must be following the syllabus requirements for the Antenna and Wave Propagation practical course in the Electronic Engineering Education Study Program, Faculty of Engineering, Universitas Negeri Yogyakarta.

After obtaining a learning media design that fits the course syllabus requirements, the next step is to make a learning media prototype and then validate the learning media prototype. This is useful to determine the feasibility and evaluate the Arduino-based high-frequency signal data acquisition equipment that has been made. The validation of the learning media prototype was carried out by lecturers from the Department of Electronic Engineering Education, Universitas Negeri Yogyakarta, as material experts and media experts. Based on the results of the learning media validation, if a revision is needed, a design revision will be carried out.

The final stage in this research is testing learning media products by testing the learning media on students as users in the learning process. The trial process is carried out by providing the learning media to students to use in practical activities. This aims to determine

how feasible the product can be used as a learning medium in Antenna and Wave Propagation practice courses.

Evaluation is the final stage of the ADDIE development model. This stage assesses the quality of the media in terms of the feasibility and suitability of the material. The results of this evaluation can be used to determine the level of feasibility and suitability of the material from the learning media developed with the Antenna and Wave Propagation course syllabus.

C. Data Collection Methods

Data collection was carried out using a questionnaire assessment sheet. Questionnaires or questionnaires are data collection techniques that are carried out by giving questions or written statements to respondents to answer[20]. The use of a questionnaire was chosen in this study because the data obtained was in the form of a score.

This research questionnaire uses a Likert scale with very positive to very negative gradations to obtain data. Convert score values with an even pattern, namely as many as four pieces adjusted to the statement pattern. The conversion scores in this study are Strongly Agree (SA), Agree (A), Disagree (D), and Strongly Disagree (SD), which can be seen in the following table.

Table 1. Table of statement patterns.

Category	Meaning	Score
SA	Strongly Agree	4
A	Agree	3
D	Disagree	2
SD	Strongly Disagree	1

D. Instruments

Instruments are used to obtain data. The research instrument is an instrument in the form of a question created as a research aid to collect data by researchers when taking measurements [21]. Instruments are used in research to make it easy for researchers to collect and analyze data.

The instrument grid used in this study was made based on the theory of evaluation of instructional media. This study uses the instruments used in the research "PID Controller Trainer as a Learning Media for Control System Practices" conducted by Marpanaji, et al [12]. The instruments used in this study were adapted to the learning media studied in this study. Assessment of learning media includes: (1) Content aspects are assessed by material experts; (2) Technical and Aesthetic aspects are assessed by media experts; and (3) Technical, Aesthetic, and Instructional aspects are assessed by users (students).

E. Data Analysis Technique

Data analysis was carried out after all data from experts and users was collected. The analysis is in the form of calculations whose results are used to answer the formulation of the problem to show the feasibility level of the learning media being researched. The data analysis stage for material experts, material experts, and users is carried out by calculating the average score. Calculation of the average score using the following formula.

$$\bar{x} = \frac{\sum x}{n} \quad (1)$$

where:
$\bar{x}$ = core average
$\sum x$ = total of assessor's score
n = number of assessors

The results of the average score obtained are then converted into a percentage value and used to classify the feasibility level of the learning media made. Equation (2) is the formula used to calculate the eligibility percentage, and Table 2 is the interpretation of the eligibility percentage.

$$\% = \frac{Total\ score\ obtained}{The\ ideal\ score} \times 100\% \quad (2)$$

Table 2. Interpretation of percentages

No	Percentage	Interpretation
1	0% – 20%	Very bad
2	21% – 40%	Bad
3	41% – 60%	Enough
4	61% – 80%	Good
5	81% – 100%	Very Good

RESULT AND DISCUSSION

The learning media development stage in this study refers to the ADDIE development stage by Branch [19]. The Analyze, Design, and Develop stages are used for the initial product development of this learning media. The Implement and Evaluate stages are used to evaluate the products developed in this study. The following is an explanation of each of these stages.

A. Analyze

The initial stage carried out when carrying out this research activity was analysis, namely identifying problems and product development needs. The steps taken are: (1) analyzing learning objectives; (2) identifying the needs of students and learning resources; (3) determining the appropriate learning media according to learning needs; and (4) making plans for research and development of instructional media. Problem identification is made by observing and analyzing the syllabus for the Antenna and Wave Propagation course using the four steps mentioned above.

Based on the results of observations that have been made, the results of the analysis are obtained in the form of a plan for developing learning media needed for Antenna and Wave Propagation practice. The learning media created includes two media, namely Antenna Pattern Radiation Learning Media and Practicum Modules (Instructions for Use and Labsheets), to practice using these learning media.

B. Design

The learning media that will be developed is Antenna Pattern Radiation learning media which is accompanied by learning modules (instructions for use and lab sheets). The design of this learning media has 6 (six) block diagrams, namely: (1) Antenna Under Testing block as input; (2) mechanical unit blocks; (3) Rf to DC Interface blocks; (4) mechanical unit control block; (5) process block; and (6) application block as output. Following are the design drawings for each block as well as the learning module design.

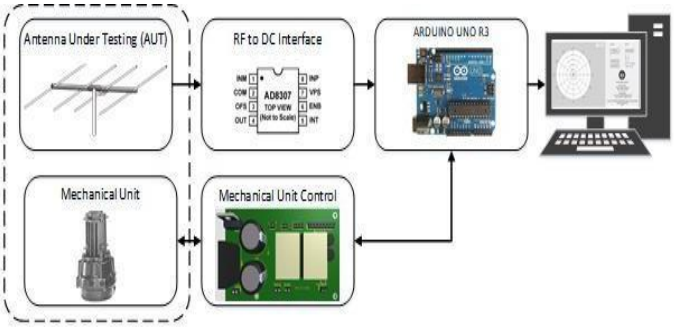


Figure 4. Developed Learning Media design blocks

C. Develop

The steps taken in this activity are to develop learning media, namely Antenna Pattern Radiation Learning Media, along with practicum modules. The steps taken are as follows:
(1) create and produce learning media:

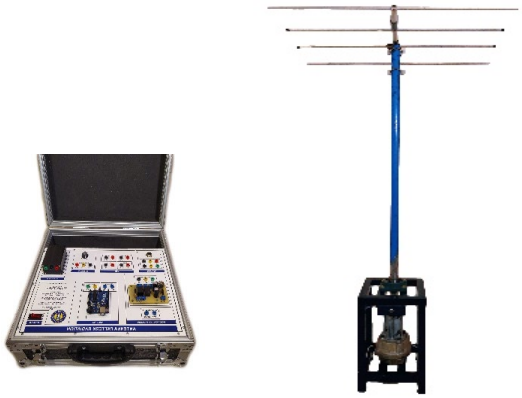


Figure 5. Media Developed learning

(2) create learning practicum modules;

Figure 6. Developed Learning Media Module

(3) testing the functionality of learning media

Table 3 shows the results of testing the functionality of the learning media that have been made:

Table 3. Performance results

No	Block	Component	Error
1	Power Supply	Adapters 12 V	0.1 %
2	RF to DC Interface	AD8307	0.5 %
3	Mechanical Unit	Kenpro KR 400	0.1 %
	Total Percentage Error		0.7 %

Testing the functionality of this learning media is also carried out by measuring the radiation pattern of the dipole antenna. As it is known that the dipole antenna 2 has a radiation pattern factor with the formula[22] :

$$E = \frac{coscos\,[(\pi/2)cos\theta]}{sin\theta} \quad (3)$$

Based on this formula, if shown in graphical form, a pattern will form as follows:

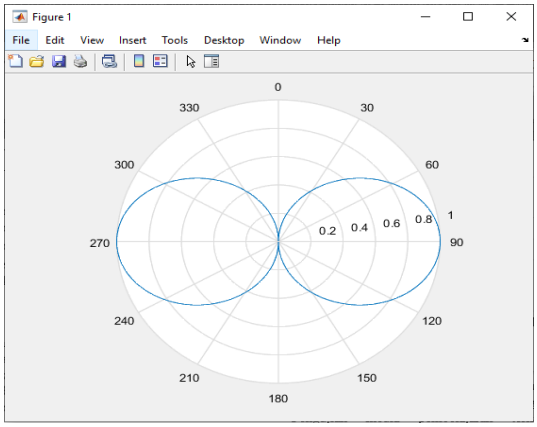


Figure 7. The Radiation pattern of a $\lambda/2$ dipole antenna.

Testing of this learning media is done by measuring the radiation pattern of an antenna mounted on a radio receiver and radio communication transmitter as a generator of electromagnetic waves. The frequency band used is Very High Frequency (VHF). Radio communication transmitters function to emit electromagnetic waves into the air. While the antenna to be tested is placed on a mechanical system that can rotate from $0^o$to 360^o. Furthermore, the measured antenna is connected to the receiving system with output as an indicator showing the amount of power received. This value will produce an indicator value representing the antenna radiation pattern from an angle of $0^o$to 360^o [23]. The antenna measurement configuration is described in the following figure[24]:

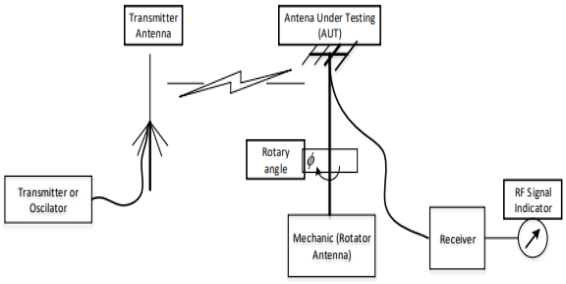


Figure 8. The process of measuring a dipole antenna

When measuring the antenna, the distance between the transmitting antenna and the receiving antenna must consider the nature of the electromagnetic field emitted from the antenna. Thus, the measurement results obtained truly represent the electromagnetic field of the

antenna being tested [25]. The electromagnetic field on the antenna can be divided into 2 (two) electromagnetic field fields, namely the Fresnel Zone and the Fraunhofer Zone [22]. The boundary of this area is determined by the distance (radius), which is determined by the length of the antenna, which can be described as follows:

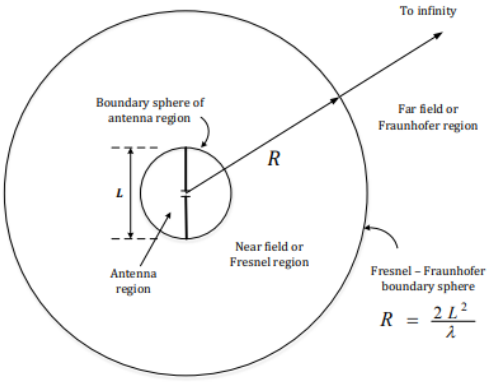


Figure 9. Antenna field area (Fresnel Region and Fraunhofer Region)

The discussion above shows that if we are going to measure antenna parameters, then the location of the antenna to be measured with the measurement point must be in the Fraunhofer area or the measurement distance fulfills the equation [26].

$$R = \frac{2L^2}{\lambda} \qquad (4)$$

The test results of this tool are then used to describe the radiation pattern of the dipole antenna as shown in Figure 10 below.

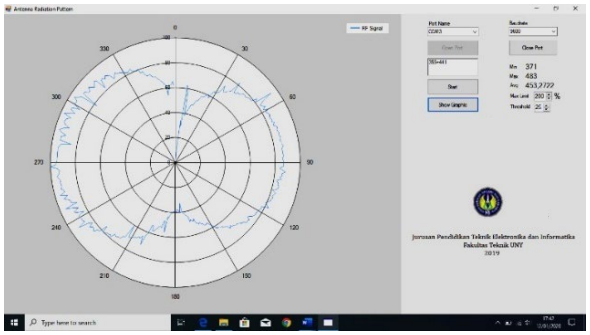


Figure 10. Test results for measuring dipole antennas

After the system functionality test was completed and it turned out that the radiation pattern measuring system could work properly, the media and practice modules were evaluated by material experts and media experts. This evaluation is carried out before the learning media is tested on users (students).

Material validation is carried out so that the learning media has good material quality by validating the content aspect. This validation was carried out by 2 material expert validators. In addition to content validation, construct validation is also carried out on learning media so that it has a good quality learning media by validating technical aspects and aesthetic aspects or from a media perspective. This validation was also carried out by 2 media expert validators.

The data collection process was carried out to validate the material expert and media expert validation by using a questionnaire given to the validator. Figure 11 below shows the percentage of the validation assessment of material experts and media experts on Antenna Radiation Pattern Learning Media.

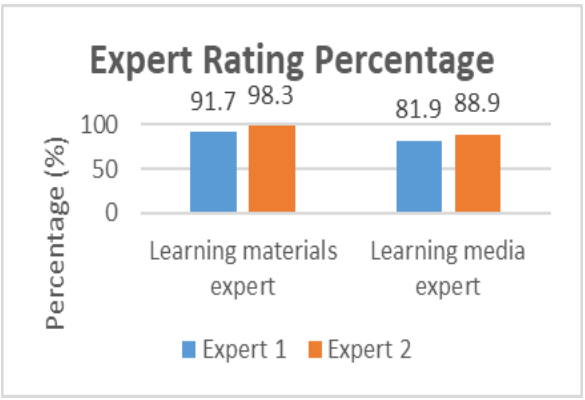


Figure 11. Graph of Expert Rating Percentage

D. *Implementation*

After the learning media has been validated, the next step is to test the learning media on users. Testing learning media on users is carried out by providing learning media to semester 5 students of the Electronic Engineering Education Study Program, Department of Electronics and Informatics Engineering, Faculty of Engineering, Universitas Negeri Yogyakarta.

Testing was carried out by testing learning media for practical activities in Antenna and Wave Propagation courses. The following are the results of testing the Antenna Pattern Radiation learning media product. Based on the results of data collection from users, the percentage of ratings is obtained. Figure 12 below shows a graph of the percentage of user ratings.

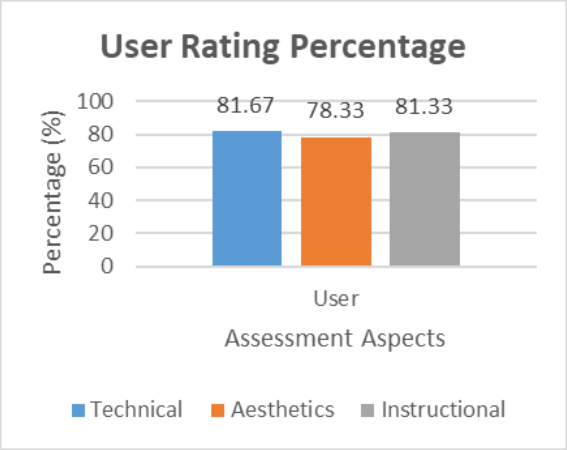


Figure 12. User Rating Percentage Graph

E. Evaluate

The final stage in developing instructional media in this research is product revision which is carried out based on the results of functional tests as well as criticism/suggestions and input from material experts, media experts, and users. The purpose of the revision is to improve the quality of the developed learning media products.

The results of the functionality test are shown in Table 3. Based on this table, there is an error of 0.7%. The test results for measuring the dipole antenna shown in Figure 10 are similar in pattern to the theory of the dipole antenna radiation pattern shown in Figure 7. The criticism obtained is that there are several images in the learning module that are too small and the use of a rotator motor that is too large.

The results of the test to measure the dipole antenna are indeed different from the theory of the radiation pattern of the dipole antenna in terms of accuracy in describing the radiation pattern. However, the results of these measurements have shown the radiation pattern of the dipole antenna, as shown in theory. To find out how far the difference between the measurement results and the theory is, further research can be carried out.

Criticism and suggestions were not fully responded to and followed up due to several limitations (time, cost, and availability of components). The corrections made followed up on suggestions about some of the images in the learning module that needed to be bigger. This was considered important because of the visibility or readability of the module.

CONCLUSION

The results of the research that has been done show that the Antenna Pattern Radiation learning media is rated by material experts at 95%, by media experts at 85.4%, and by students/users at 80.65%. The assessment results of Material Experts, Media Experts, and Users show that the Antenna Pattern Radiation learning media is included in the very feasible category and can be used as a learning medium in Antenna and Wave Propagation courses.

Furthermore, there are several suggestions from experts and users as input for further research to improve the quality of learning media, including (1) The need for further development of other radiation patterns; (2) Further research needed to determine the differences between the measurement results compared to the antenna radiation pattern theory; (3) It is necessary to develop the mechanical unit so that it can rotate faster; (4) Reduction in the connection of less tidy jumper cables.

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