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Implementing Problem-based Learning using Multimedia to Improve Cognitive Students

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ABSTRACT

The 2016 UNESCO Global Education Monitoring (GEM) Report explained that Indonesia ranked fifth from the bottom among 14 other developing countries in terms of education quality. Quality education should not only focus on results but also emphasize the learning process. The purpose of this research is to apply the Problem-Based Learning (PBL) model in multimedia to improve students' cognitive abilities as part of problem-solving techniques. The research method used is R&D with the ADDIE multimedia development model and a One-Group Pretest-Posttest research design. The findings indicate an improvement in students' cognitive abilities through the application of the PBL model in informatics learning multimedia. This improvement in cognitive abilities demonstrates an enhancement in students' problem-solving skills. Since cognitive aspects are integral to problem-solving techniques, an increase in cognitive ability corresponds to better problem-solving skills. Additionally, the improvement is evident in the student's learning outcomes, which increased from an average of 62.17 (pretest) to 80.33 (post-test). The t-test results confirmed that the increase in student learning outcomes was statistically significant. Furthermore, the average score of student responses to the multimedia was 84.4%, categorized as “Very Good.”

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1. INTRODUCTION

The low achievement of students reflects the low quality of Indonesian education (Wahyudi et al., 2022). Similarly, the UNESCO Global Education Monitoring (GEM) Report 2016 explained that Indonesia ranks fifth from the bottom out of 14 other developing countries in terms of education quality. According to research conducted by Nuryana and Rosyana (2019) on high school students regarding their problem-solving skills, it was found that these skills tend to be low. Students are not familiar with solving problem-solving tasks, making it difficult for them to understand the information in the problem and find solutions. This finding indicates that learning does not sufficiently improve students' problem-solving abilities, as teachers rarely involve discussion processes in learning—either between students or between students and teachers. This is unfortunate because such discussions can provide students with opportunities to exchange information and analyze data sources to formulate solutions to problems (Gumanti et al., 2023).

The low problem-solving abilities of students need to be addressed effectively, as they impact both the learning process and outcomes (Aripin, Sahidu, and Makhrus, 2021). Problem-solving skills can be improved using cognitive-based techniques, one of which is cognitive learning. According to Sugiyono (2015), cognition refers to the thought process, which is the ability of individuals to connect, assess, and evaluate events. Cognitive abilities develop gradually, in line with physical development and the development of the central nervous system. Cognitive development theory is widely used to explain this process, where cognition is considered as a set of mental tools that are essential for problem-solving. However, the implementation of the Problem-Based Learning (PBL) model in schools has not been optimal. In interviews with the informatics teacher at SMAN Cimanggung, they mentioned, "The PBL model is used in learning, but students tend to lack interest and confidence, thinking that the problems being studied are difficult to solve, so they hesitate to try."

Therefore, this research aims to design a learning process that applies the Problem-Based Learning (PBL) model using multimedia to improve students' cognitive abilities. The results of this design will be applied to informatics subjects, specifically in the Algorithms and Programming (AP) topic, with a focus on searching and sorting materials. The reason for selecting algorithms and programming as the research topic is because this material is fundamental in Informatics education. Students are expected to enhance their logic and digital technology skills—learning how to understand and recognize problems and thinking sequentially and systematically to solve them (Panggayuh, 2017). The Algorithms and Programming topics are particularly effective in honing students' problem-solving abilities.

The choice of algorithms and programming is also motivated by common challenges in learning these subjects. According to Gandara, Sumarwan, and Hannan (2021), one difficulty students face is translating computerized language such as code. While student can understand specific examples provided by the teacher, they struggle to apply their understanding to other, similar examples. This issue arises even when the examples are conceptually related (O'Kelly et al., 2004). Therefore, this research seeks to implement the PBL model in multimedia-assisted learning for informatics, focusing on the algorithms and programming elements—specifically on searching and sorting—to improve students' cognitive skills as part of problem-solving techniques. Consequently, this research is titled "Implementation of Problem-Based Learning in Informatics Learning Multimedia to Improve Cognitive Skills of High School Students."

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2. METHODS

The research method used in this study is the Whole Life Cycle Multimedia Development (Siklus Hidup menyeluruh or SHM) method. This approach is chosen because the aim of this research is to develop a product in the form of interactive multimedia. According to Munir (2012), multimedia development consists of five stages: analysis, design, development, implementation, and evaluation.

The research design employed is the One-Group Pretest-Posttest Design. This design includes a pretest conducted before the treatment is applied. As a result, the post-treatment outcomes can be more accurately assessed, as it allows for a comparison of the results before and after the intervention. Based on this explanation, the One-Group Pretest-Posttest design can be presented in **table 1**:

Table 1. Desain *One-Group-Pretest-Posttest*

Pretest	Treatment	Posttest
O_1	X	O_2

Explanation:
O_1 : Pretest results (before treatment)
X : Experimental treatment
O_2 : Posttest results (after treatment)

2.1. Research Population and Sample

The population in this study was students of SMAN Cimanggung. The research sample consisted of students from class X of SMAN Cimanggung. Sampling in this study used a non-probability sampling technique, specifically purposive sampling, which involves selecting a sample based on the consideration that it aligns with the issues raised in the study. The sample was selected using a convenience sampling technique, meaning that the sample was chosen based on the availability of elements and the ease of obtaining them (Sugiyono, 2015).

2.2. Research Instruments

Research instruments are used to collect data from the conducted research. The instruments used in this research are, for the field study instrument, interviews, and questionnaires. Question Instrument, To assess students understanding of the material taught, a question instrument on basic computer and network concepts is needed. The question is designed by applying and incorporating components of computational thinking to test students' computational thinking skills. Assessment Instrument for Expert Media, the instrument used refers to the User Acceptance Technique (UAT). Student Response Instrument to Media, the response instrument was developed by the researcher based on aspects of the Technology Acceptance Model. (TAM).

2.3. Data Analysis Techniques

Research Data Analysis of Field Study Instruments: In this section, the researcher conducts an analysis of the field study based on the data obtained from teacher interviews and preliminary student questionnaires. Analysis of the Question Instrument: The data from the question instrument is taken from the results of testing conducted first on students who

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have studied the material on network planning and addressing. The types of tests used are as follows. Validity test, reliability test, difficulty index, discrimination power. Hypothesis testing analysis, paired T-test is used to find the significance of the average. The normality test is conducted to determine whether the data obtained from the research is normally distributed or not. The analysis of the instrument data, both media and materials that have been obtained or validated, will be analyzed using a rating scale. The analysis of the instrument data regarding student responses after using the developed learning media will be conducted using a Likert scale. Normalized Gain (N-Gain) Analysis Normalized gain, or gain test, is used to measure students' computational thinking abilities in answering various problems related to the indicators of computational thinking after treatment has been applied. The formula for gain can be seen in the following **equation 1**.

Equation 1. N Gain

$$g = \frac{T_2 - T_1}{T_3 - T_1}$$

The n-gain test is calculated by determining the average and gain values from the pretest and posttest, and then the results are categorized into three criteria: low, medium, and high, as explained in **Table 2**.

Table 2. N Gain Analysis Classification

Score N Gain	Category
g > 0,7 High	High
0,3 ≤ g ≤ 0,7	Middle
g < 0,3	Low

3. RESULTS AND DISCUSSION

3.1. Analysis Phase (Analyze)

In the analysis stage, the initial research begins with the aim of understanding the learning conditions and identifying the problems that occur. This phase establishes the software development requirements by considering the teaching and learning objectives.

3.1.1. Literature Study

The purpose of the literature review procedure is to gather data that supports research related to learning, which will be the focus of the study. At this stage, a literature review is conducted by gathering various hypotheses related to the research field being studied. Therefore, the aim of this literature study is to obtain a strong theoretical framework that will serve as the foundation for the planning and implementation of this research.

3.1.2. Field Study

The questionnaire was given to 30 students who had studied computational thinking elements; this questionnaire emphasized the problems and learning difficulties in BK material. Based on the results of this questionnaire, 63.3% of students have difficulty in

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learning BK; the difficulty of learning BK is experienced most in sorting material, with 83.3% of respondents, and least in stacking material, with 40% of respondents. As many as 80% of respondents had difficulty learning to search. 43.3% of respondents had difficulty learning to queue. The factors causing students to have difficulty understanding the material are analyzed in this section. It is known that 25, or 83.3%, of respondents stated that the most common factor causing students to find it difficult to understand the material is that the learning process is not interactive and interesting. In addition, 73.1% of respondents stated that the learning media used during monotonous learning (limited to textbooks and PowerPoints) was one of the factors causing students to have difficulty understanding the material, and 42.3% of respondents thought that the teacher's way or pattern of delivering material that was less interesting and did not increase learning motivation was also one of the other contributing factors.

3.1.3. User Analysis

The users of this web-based interactive multimedia problem-based learning are students in the first year of senior high school who are studying basic informatic.

3.1.4. Software Needs Analysis

This research will utilize web-based learning media through a learning management system (LMS), with Moodle being the platform that will be designed and developed in this study. In the design and development process, the researcher will use software that assists in creating web-based media. This software program includes. Operating System, Microsoft Edge and Google Chrome browsers, Canva, XAMPP, Idcloudhost, Visual Studio Code.

3.2. Design Phase (Design)

In the design stage, researchers begin to create and develop concepts for the design of learning and interactive multimedia. The activities carried out by the researchers at this design stage are as follows:

3.2.1. Learning Design Planning

In the preparation of learning plans, the preparation is carried out with reference to the learning outcomes set by the government. The determination of learning outcomes is based on the curriculum used at the research site. The curriculum used in this study is an independent curriculum. In general, the content includes the initial plan of materials or topics that will be taught in the learning media. There are 2 topics that will be presented. searching and sorting Instrument Design: At this stage, researchers will design questions about searching and sorting by including aspects of computational thinking. Preparation of teaching modules to explain the general description of learning that will be carried out in more detail.

3.2.2. Media Design Planning

At this stage, researchers create flowcharts that are used to provide a structured and easy-to-understand visual representation of the sequence of processes in the media created. The use case diagram design stage is to show features and menus that cannot be accessed by certain users. The following **figure 1** illustrates the use case diagram.

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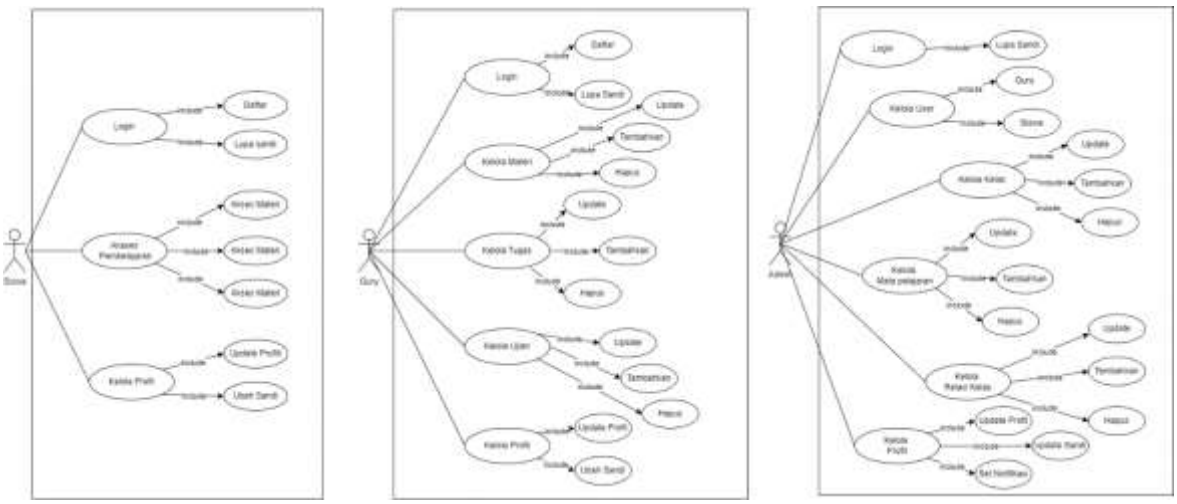

Figure 1. Use Case Diagram

In the picture above, there are three actors who have access to the media. Admin has access to login, create courses, update courses, manage courses, and also update profiles. admin has access to manage users, Teachers have access to manage courses, update courses, manage activities, create activities, update activities, delete activities, and give grades. Students can login and register an account, access the LMS, take pretests and posttests, view grades, view materials, and view profile updates.

Storyboards are images or sketches of media designs that are arranged sequentially based on the story that will be created by researchers, especially the pages that will be included in the media. It is also aligned with the stages of problem-based learning to facilitate the creation and application of media.

3.3. Development Phase (Design)

This stage is the development phase of interactive multimedia based on the flowchart and storyboard, along with the necessary equipment that has been prepared in the design phase. This stage also includes the process of developing the multimedia interface design and testing the multimedia. Before moving on to the next stage, an expert media validation is conducted at this stage to obtain critiques and feedback so that the developed interactive multimedia is appropriate and suitable for use.

3.3.1. Development of Media Interface Design

The initial process of creating Eduvers learning multimedia begins with the design and development of the interface. This step involves translating the mockups and storyboards that have been previously created into a functional interface. The design of the interface follows the flowchart that has been carefully planned to ensure a seamless and logical progression of interactions. By adhering to these visual and structural guidelines, the interface is crafted to provide an intuitive user experience, ensuring that student can easily navigate through the content and activities within the multimedia platform. The following **table 3** illustrate the user interface of the multimedia.

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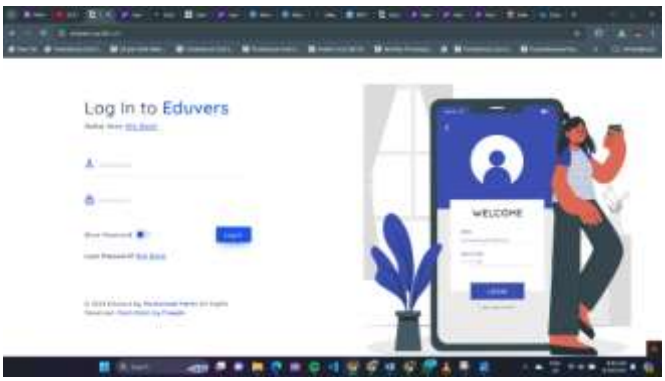
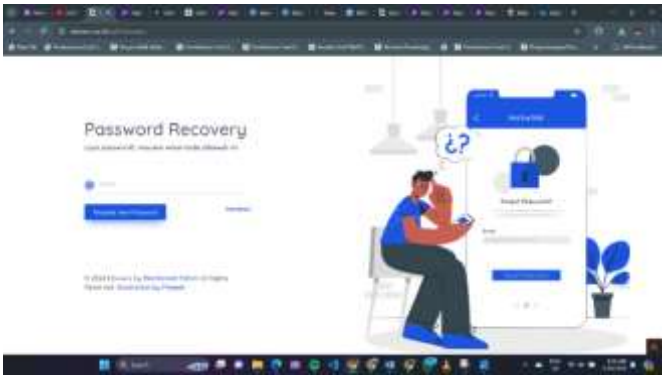
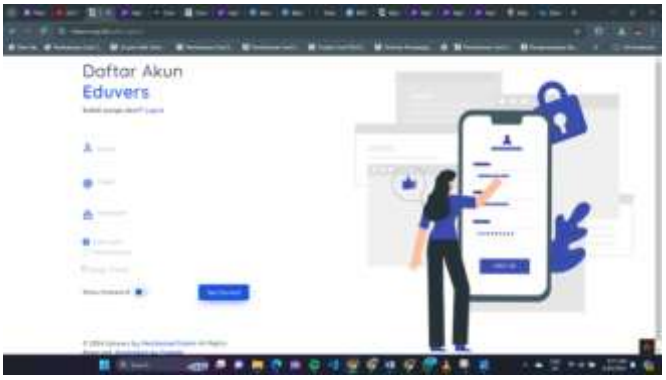
Table 3. Interface Design Flow

Interface	Description
	Used to log in for users including admin, teachers, students.
	Change the password if the user forgets the password that has been created.
	Register as a new user, can register as a teacher or as a student

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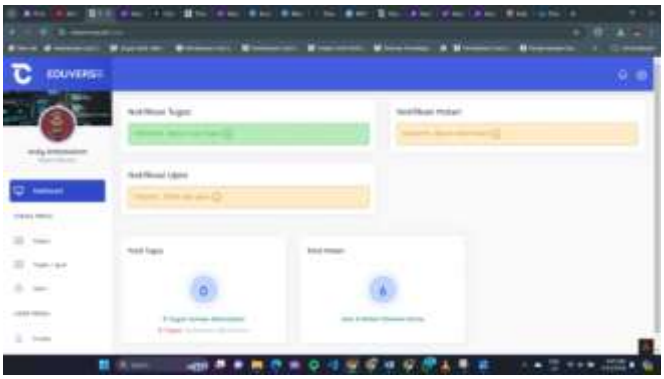
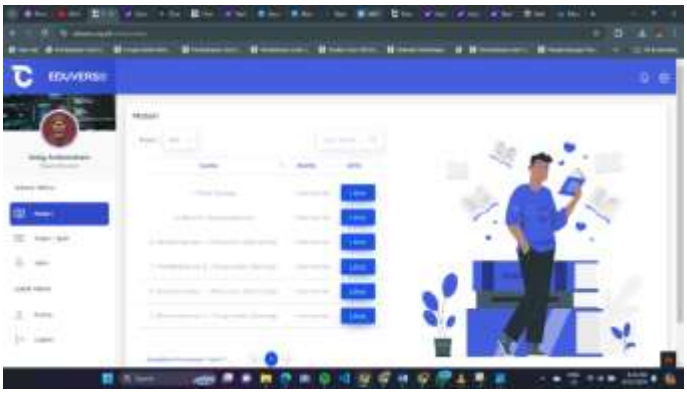
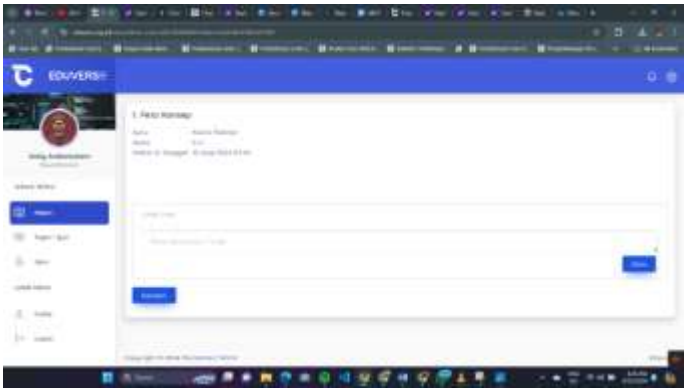
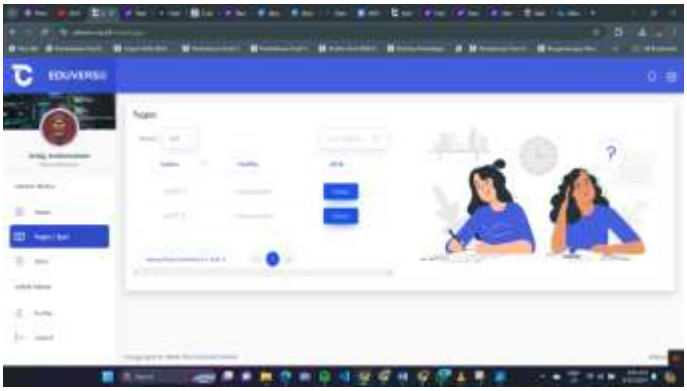
p- ISSN xxxx-xxxx e- ISSN 2774-7891

	Dashboard displays notifications and also student activities that have been carried out.
	The material displays a sequence of materials that the teacher has created to work on.
	Displays details and material files.
	Task displays the order of the student worksheet.

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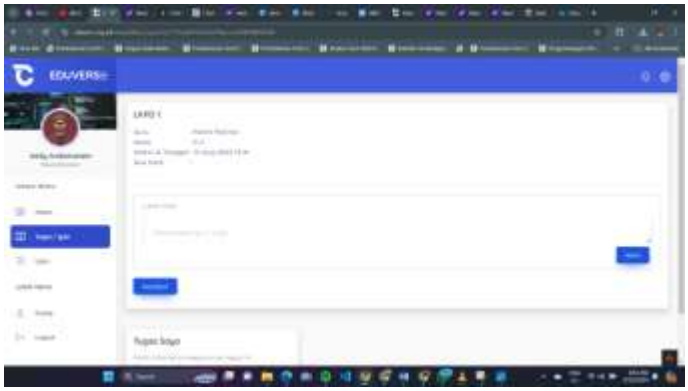
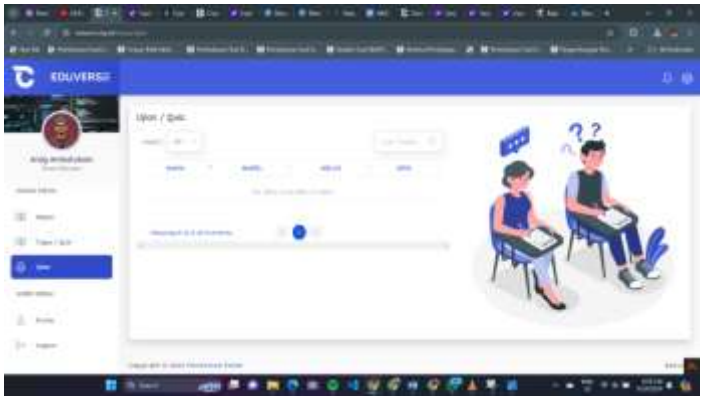
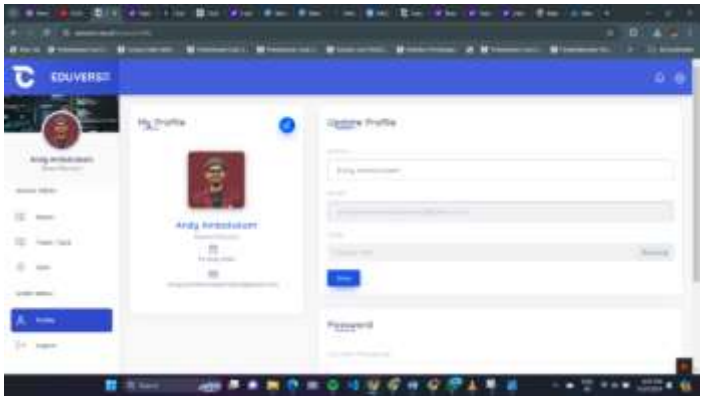
	Displays the details of the student worksheet.
	Displays the exam that has been created by the subject teacher.
	Update profile and change password.

3.3.2. Media Validation by Experts

After the media is completed, the next step is validation by experts. The instrument used for validation refers to the user acceptance testing (UAT). This test was conducted by 1 lecturer and 1 teacher of Informatics.

After the development and improvement process of the created media, the final validation result from the expert lecturer was accepted at 85%, and the validation result from the expert teacher was accepted at 94.15%. From the average percentage of the two validation results, a combined average of both results was obtained at 89.58%, as shown on the following **figure 2**.

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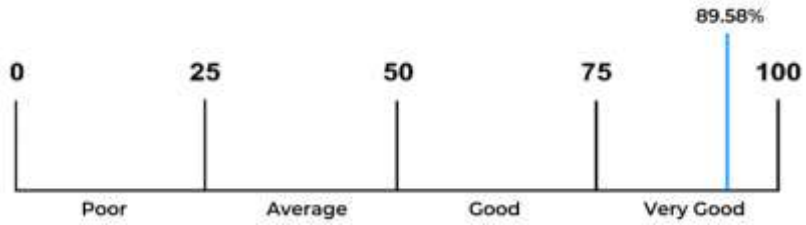

Figure 2. Scale of Expert Media Validation Results

3.4. Implementation Phase (Implement)

The implementation stage is carried out by applying all components that have been prepared from the analysis to the design stage to students. The implementation of learning was carried out at SMAN Cimanggung. The preparation of teaching modules as a learning plan in the Merdeka curriculum is made in advance before carrying out the learning process. This teaching module contains module identity, initial competence, Pancasila learner profile, facilities and infrastructure, target student, learning model, core components, learning objectives, meaningful understanding, triggering questions, learning preparation, learning activities, and evaluation. The implementation stage is carried out through three main stages consisting of giving pretests, learning actions, and giving posttests, as well as one other stage, namely filling out a learner response questionnaire.

3.4.1. Pretest

The first implementation stage involves students filling out the pretest questions on PBO material. The pretest consists of 20 multiple-choice questions on BK material. The questions used are deemed valid based on the validation results. Students complete the BK material pretest provided. After finishing and submitting their answers, the points and the results of correct and incorrect answers will be displayed.

3.4.2. Treatment

In the learning action or treatment stage, Eduvers learning multimedia is used to facilitate students in accessing material and following the intended learning flow. The learning flow is based on the analysis stage, which adjusts the use of learning multimedia to the planned learning stages. In this study, all learning activities were conducted according to the stages of the PBL model that had been applied in the Eduvers learning multimedia.

Learning actions were carried out over 2 meetings, each following the pretest-action-posttest cycle to measure the initial and final abilities at each meeting. The material covered in each meeting was different, with the first meeting focusing on the searching algorithm and the second meeting covering the sorting algorithm.

3.4.3. Posttest

The first implementation stage involves students filling out the posttest questions on PBO material. The posttest consists of 20 multiple-choice questions on BK material. The questions used are deemed valid based on the validation results. After completing the pretest on BK material, students submit their answers. Once the students have finished and submitted their answers, the points and the results of correct and incorrect responses will be displayed.

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3.5. Assessment Phase (Assessment)

At this stage, the data obtained through the pretest and posttest were analyzed. The question instruments used were 20 multiple-choice questions each. The results of the pretest and posttest can be seen in the attachment sheet. In addition, several tests were carried out, such as the normality test, paired t-test, and N-gain test.

3.5.1. Student Test Data

Initial data, which includes pretest, posttest, and student responses to the media, will be collected after the implementation phase.

1) **Normality Test**

The Shapiro-Wilk test is used to test the normality of data in SPSS. The basis for the Shapiro-Wilk decision is that data is considered normal if the significance is greater than 5% or 0.05.

Table 4. Results of Normality Test

Type of Test	Statistic	Df	Sig.
Pretest	0.956	30	0,241
Postest	0.956	30	0,241

Based on the results in the **table 4**, the pretest and posttest data are normally distributed, with a pretest and posttest Sig. value of 0.241, indicating that H0 is accepted and H1 is rejected because the Sig. values are greater than 5% or 0.05.

2) **N Gain Pretest and Posttest Test**

The N-gain calculation is conducted to determine whether there has been an improvement in student learning outcomes after the treatment has been implemented.

Table 5. Table of Gain Test Results by Group

Group	Average Pretest	Average Posttest	N-Gain Score	N-Gain Percentation (%)	Categori
Upper	76,66	93,33	0,71	71,66	High
Middle	61,8	80	0,48	48,61	Medium
Lower	45	65	0,35	35,83	Medium

The results of the gain test in **table 5** show that all groups experienced an increase in scores. The upper group has a gain value of 0.71, which is categorized as "High"; the middle group has a gain value of 0.48, categorized as "Medium"; and the lower group has a gain value of 0.36, also categorized as "Medium."

3.5.2. Students Responses to Media

The learner response questionnaire was conducted after the research process. The questionnaire used refers to the Technology Acceptance Model (TAM). Respondents who filled out the questionnaire were 30 students who interacted directly with Eduvers learning multimedia. The results of filling out the learner response questionnaire are shown in Appendix 45, and then the results of data processing can be seen in **Table 6.**

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Table 6. Results of the Learner Response Questionnaire to Eduvers Learning Multimedia.

No	Assessment Aspect	Number of Items Ideal	Ideal Score	Acquisition Score Percentage (%)	Percentage (%)
1.	Perceived Usefulness	6	900	737	81,89
2.	Perceived Ease of Use	6	900	809	89,89
3.	Attitude Toward Use	2	300	241	80,33
Average					84,04

80.33%. The average percentage value obtained from the results of students' responses to Eduvers learning multimedia is 84.04%, which is included in the "Very Good" category, as shown in **figure 3.**

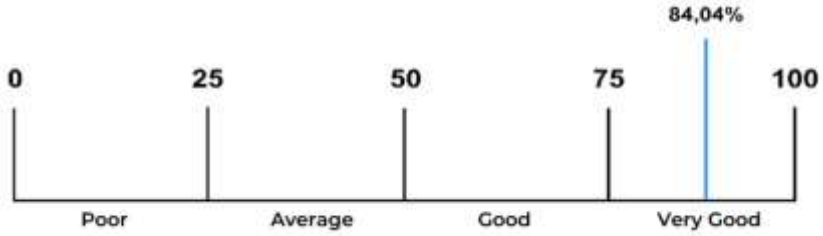

Figure 3. Scale of Student Response Results

After analyzing student responses to the media using a rating scale technique, the researcher will next use the SmartPLS 4 application to analyze the results of the TAM instrument. **Figure 4** explains the result of the calculation.

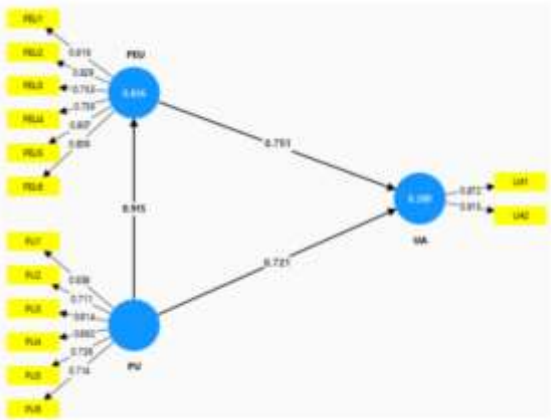

Figure 4. Results of Smart PLS Calculation

Shows the results of the validity test of the TAM learner response instrument. The validity test results show that each variable item has a loading factor value > 0.500. Thus, the question items on each variable are valid. This shows that the question items are suitable for variable references; indicators have met convergent validity or can already represent one latent variable and underlie the assessment of the latent variable. Table 4.24 shows the reliability test on the TAM results. The TAM reliability test results show that the Cronbach alpha value for each PEU, PU, and AU-IT variable has a value of more than 0.700.

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This can prove that all variables are reliable. Thus, all TAM variables used, such as the perceived ease of use, perceived usefulness, and perceived acceptance of TAM in this study, can be trusted or reliable to be used as variable measuring instruments.

Table 7 to 9 shows the significance test of TAM results. Based on the results shown in **table 7 to 9**, it is known that all P values or path analysis results to determine the relationship between each TAM variable are less than 0.005. Thus, it can be statistically concluded that all TAM hypotheses, namely H1, H2, and H3, are acceptable. This shows that:

- There is acceptance of H1 where the perceived ease of use variable has a positive influence on the acceptance of Eduvers learning multimedia.
- There is acceptance of H2 where the perceived use variable has a positive effect on the acceptance of Eduvers learning multimedia
- There is acceptance of H3 where the variable perceived ease of use and perceived use together have a positive influence on the acceptance of Eduvers learning multimedia.

Table 7. Loading Factor Table (Validity Test)

Variabel	Item		Loading Factor	Description
PEU	PEU1		0,792	Valid
	PEU2		0,757	Valid
	PEU3		0,600	Valid
	PEU4		0,757	Valid
	PEU5		0,509	Valid
	PEU6		0,642	Valid
PU	PU1		0,591	Valid
	PU2		0,757	Valid
	PU3		0,742	Valid
	PU4		0,673	Valid
	PU5		0,760	Valid
	PU6		0,757	Valid
AU-IT	AU-IT1		0,950	Valid
	AU-IT2		0,963	Valid

Table 8. Alpha Cronbach Table (Reliability Test)

Variabel	Alpha Cronbach	Description
PEU	0,764	Reliable
PU	0,810	Reliable
AU-IT	0,907	Reliable

Table 9. Causal Relationship Table (Relationships Between Variables)

Kausal	P
PEU → AU-IT	0,000
PU → AU-IT	0,002
PEU, PU→ AU-IT	0,000

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4. CONCLUSION

The design of problem-based learning multimedia refers to the ADDIE stages. At the analyze stage, it is concluded that there are several problems in learning search and sorting. Starting from the problem of problems from the student side, learning media, and learning methods used. In addition, it is also found that the Problem-Based Learning model is suitable for improving students' cognitive abilities. At the design stage, it was concluded that the multimedia design was ready to be developed, and 20 pretest questions and 20 posttest questions were also obtained. At the implementation stage, a multimedia assessment of 88, or very good, was obtained. At the implementation stage, learning was carried out in as many as 3 meetings including pretests and posttests. The average pretest score was 62.17, and the posttest was 80.33. At the evaluation stage, the N-Gain between the pretest and posttest was 0.47. Also obtained a TAM questionnaire value of 84.04 is "Very Good."

5. ACKNOWLEDGMENT

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6. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. Additionally, the authors confirm that the paper is free from plagiarism.

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