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Development of E-module of Fluid Physics Based on Problem-Based Learning (PBL) to Improve Motivation and Learning Outcomes of Grade XI Students of SMAN 4 Bagan Sinembah

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A B S T R A C T

Technological advances have an impact on the use of learning media used in schools. This causes educators to develop teaching media that are appropriate to students' needs. One of the teaching media that can be designed according to students' abilities is e-modules. Initial findings indicate that the dominance of the use of less attractive printed books reduces students' motivation and learning outcomes. The purpose of this study was to develop a fluid physics e-module based on Problem-Based Learning (PBL) to improve motivation and cognitive learning outcomes of grade XI high school students. The method used was Research and Development (R&D) with the ADDIE model. Research data came from needs analysis, expert validation, teacher and student response questionnaires. The implementation stage of this PBL data used Nonequivalent Control Group Design and the data viewed were motivation data and cognitive learning outcomes. The results showed that the e-module developed obtained valid criteria by expert validators, and practicality by teachers and students obtained a very good category. The experimental class using the e-module showed higher motivation and cognitive learning outcomes than the control class. Data were analyzed using MANOVA which showed an increase in learning motivation by 52.9% and cognitive outcomes by 30.1%. The PBL e-module has proven to be effective and feasible to implement to improve physics learning.

1. Introduction

The quality of education in Indonesia is still low. The TIMSS 2015 study ranked Indonesia 46th out of 51 countries (average score 397) (Lestari et al., 2024). PISA 2022 also showed similar results, with Indonesia in 69th position out of 81 countries. Indonesian students' reading (359), mathematics (366), and science (383) literacy scores were far below the global average (OECD, 2023). The data shows the low mastery of students in physics, one of the branches of science. This is concerning because physics studies natural phenomena that can be observed by the senses and are often encountered in everyday life (Malina et al., 2021). Students currently experience difficulties when studying physics, especially in fluid material. Research conducted by (Nasbey & Muliyati, 2022) As many as 6% of students are classified as understanding the concept of fluids, while 28% have misconceptions related to the material and as many as 30% of students are included in the category of not understanding the concept.

Another factor that causes fluid physics material to be less popular with students is that teachers still tend to use physics learning methods that are less diverse. The results of the initial needs analysis study through a needs analysis questionnaire obtained that around 50% of teachers still use the lecture method, followed by questions and answers and discussions (each 25%), indicating the dominance of conventional learning. The selection of learning models is important for student success. In addition, 50% of students are less enthusiastic and sleepy, indicating low learning motivation.

In physics, motivation greatly influences learning activities, encouraging students to complete assignments seriously to achieve goals (Putri et al., 2020). Motivation is very important to encourage students' enthusiasm, perseverance, and focus on learning. Without motivation, students' learning potential is difficult to maximize. Generating and maintaining motivation is the main key to learning in schools to increase student engagement and learning outcomes (Fernando et al., 2024).

Student motivation plays an important role in learning effectiveness. Without motivation, students tend to have difficulty achieving optimal learning outcomes, so that achievement is also affected (Chang & Tsai, 2022). Low physics learning outcomes can be caused by many factors, including: students still find it difficult to understand the material in physics books available at school, educators are less precise in selecting learning media, limited laboratory facilities cause students to be less involved in the learning process and class activity is still largely dominated by educators (Parinduri & Nurjannah, 2024).

Efforts that can be made to overcome the above problems are through the development of teaching materials. One of the teaching materials that can be developed is e-modules. E-modules are teaching materials that contain independent learning materials that are systematically arranged into certain learning units and presented in electronic format. Each learning activity is connected through a link, which makes learning more interactive (Maulida et al., 2022). In addition, well-designed e-modules can be used independently and are enjoyable for students, and have the flexibility to comply with the principles of the independent curriculum (Fitri et al., 2024). In order for effective and innovative learning using e-modules to improve students' motivation and cognitive learning outcomes, a learning model is needed that can support students' learning success, namely using the PBL model. E-modules that use the PBL model in the learning process can improve students' cognitive abilities or learning outcomes (Maghfiroh et al., 2024).

The PBL model is a learning model where this model makes problems the main point in its learning. Problem-solving skills are very much needed by students in physics learning because problem-solving activities can help students construct new knowledge and facilitate physics learning (Harefa & Gumay, 2020). In line with research conducted by Nicholus et al (2023) problem-based learning (PBL) encourages learning engagement where the problem is a real problem that is used to encourage students to be actively involved in the learning process rather than relying on information provided by the teacher. In addition, in the independent curriculum, one of the learning models that is in line with the principles of the current curriculum is the PBL model.

Based on the description above, the author developed a fluid physics e-module with the Problem-Based Learning (PBL) model to improve the motivation and cognitive learning outcomes of grade XI students at SMAN 4 Bagan Sinembah, Rokan Hilir Regency, Riau.

2. Methodology

This study uses a Research and Development (R&D) approach to develop and test a PBL-based fluid physics e-module using the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation). Data were analyzed through e-module eligibility scores from experts (material, pedagogy, media), teacher and student responses to the e-module, motivation questionnaire scores and posttest scores of learning outcomes. The study used a quasi-experimental design of the Posttest Only, Nonequivalent Control Group Design type with a population of 4 classes and a sample consisting of 2 classes. Class XI.1 as the experimental group (using e-module) and XI.4 as the control group (not using e-module). Data were collected through interviews or observations to understand students' experiences and opinions about the use of e-modules, complementing and deepening quantitative results.

The Development Techniques

The first stage, namely analysis, is the stage where researchers analyze the need for the development of fluid physics e-modules with the PBL model and the feasibility and requirements in the development procedure. This stage conducts needs analysis and curriculum analysis. The second stage is design. This stage develops e-modules as an alternative interesting teaching material to improve students' motivation and cognitive learning outcomes. The researcher divides this stage into 3 stages, namely the framework design stage, e-module creation, and assessment instrument design stage.

The third stage is development. The draft e-module that has been made at the design stage will be developed through a validation process by expert validators in their fields, small group tests, and field trials. The goal is to determine the feasibility of the e-module as a physics learning medium in the classroom. The profile framework of the e-module validation instrument by experts is presented in Table 1.

Table 1. E-module Validation Instrument Profile Framework by Experts

Expert	Assessment Aspects	Number of Assessment Items
Material	Material Suitability	5
	Accuracy of Material	3
	Material Updates	2
	User–Friendly	3
	Utilization	2
	Adaptive	1
Pedagogy	Presentation	5
	Language	3
	Constructivism	2
	Problem-Based Learning	3
	Utilization	2
	Adaptive	1
Media	Format	1
	Organization	5
	Attractiveness	3
	Typography	3
	Consistency	2
	Language	2
	Utilization	2

Source: Adapted from Hamdani et al., (2019), Januarti et al., (2023) Sari et al., (2023)

Data from the validation sheet were measured using a Likert scale with four choices indicating the level of agreement with each statement. Details of the Likert scale criteria are presented in Table 2.

Table 2. Likert Scale Assessment Categories

Mark	**Description**
1	Strongly disagree
2	Disagree
3	Agree
4	Strongly agree

An item is declared valid if it gets a minimum score of 3 from each expert assessor. The draft module is considered valid as a whole if all items meet the score limit. The validity module is determined based on the average item score compared to the established criteria as in Table 3.

Table 3. E-module Validity Categories

No	**Nilai**	**Criteria**
1	≥ 3,00	Valid
2	< 3,00	Not Valid

A small group trial was conducted to identify initial obstacles in the use of the e-module. Students were asked to fill out a questionnaire with a Likert scale and provide input for improvement. Meanwhile, the practicality of the grid instrument for teachers is presented in Table 4.

Table 4. Practicality Response Questionnaire Instrument Grid

Praktikalitas	Assessment Aspects	Number of Assessment Items
Teacher	Material	3
	Presentation	3
	Language	2
	Design	3
	Benefits	6
Students	Clarity	2
	Ease of Use	4
	Benefits	7
	Attractiveness	6

Source: Adapted from Sari et al., (2023), Yetti & Ahyanuardi (2020)

Furthermore, the percentage results of the teacher and student response questionnaire assessments were converted into quantitative values as presented in Table 5.

Table 5. Questionnaire Criteria

Average Response Score	Criteria
$3{,}25 > x \leq 4$	Very Good
$2{,}5 > x \leq 3{,}25$	Good
$1{,}75 > x \leq 2{,}5$	Quite Good
$1 > x \leq 1{,}75$	Not Good

Source: (Yennita et al., 2019)

The implementation stage of the e-module that has been declared valid will be tested in the field. The trial is carried out in classroom learning activities. The trial is carried out using a quasi-experimental research model (Quasi Experiment Design) with Posttest Only, Nonequivalent Control Group Design. The research design for this field trial can be seen in Table 6.

Table 6. Quasi Experimental Design with Posttest Only, Nonequivalent Control Group Design

Class	Post Test	Treatment
Experiment	X	O_1
Control	-	O_2

Source: (Pakaya et al., 2023)

Information:

X = Learning treatment using e-modules with the Problem Based Learning (PBL) model

O_1 = Posttest results of the experimental class using E-modules

O_2 = Posttest results of the control class not using E-modules

The ADDIE model was chosen because it is systematic and easy to follow in creating learning products. The research procedure is illustrated in Figure 1.

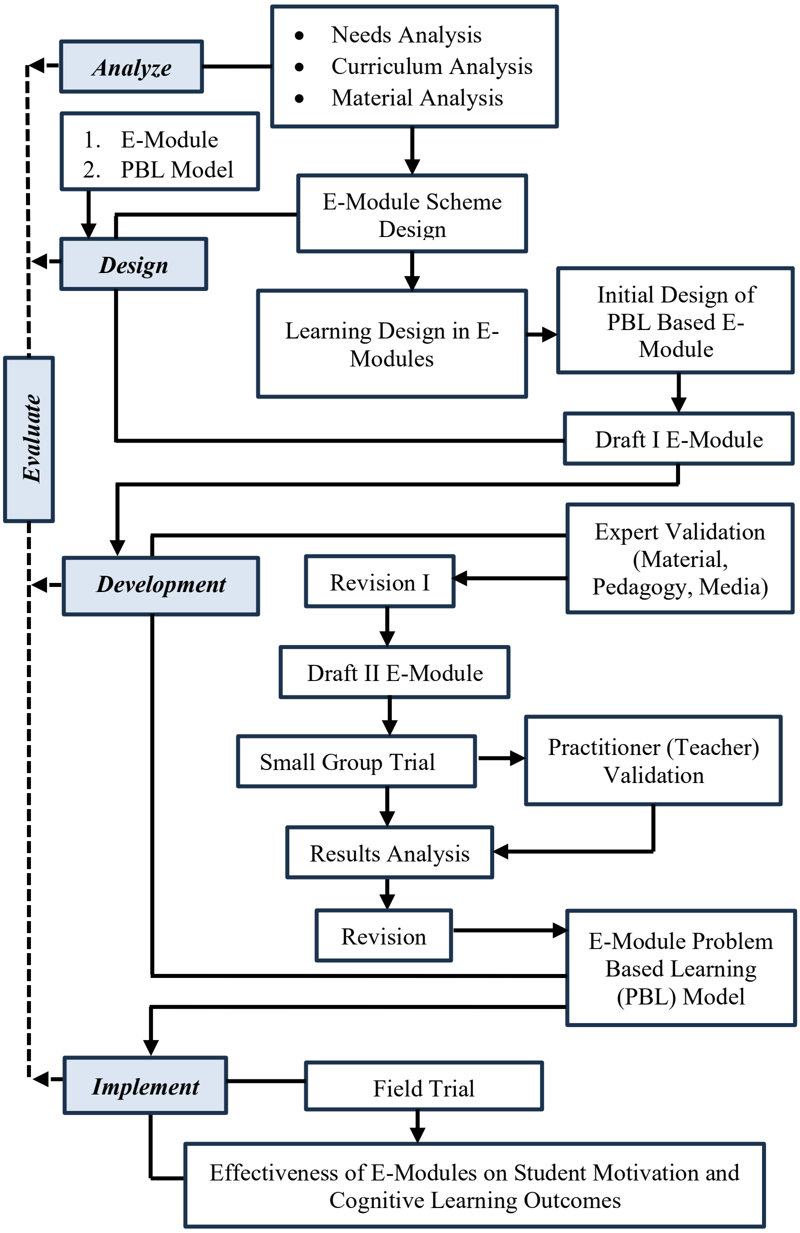

Figure 1. Research Procedure

The evaluation stage is a stage related to all stages. In this stage, the researcher will evaluate all deficiencies in each stage and correct these deficiencies according to the suggestions and recommendations obtained. The learning effectiveness test is divided into two stages, namely descriptive and inferential analysis. This descriptive analysis aims to identify differences in students' motivation and cognitive learning outcomes between the experimental class (which uses fluid e-module-based learning with the PBL model) and the control class (which uses physics books from school). The criteria for assessing students' cognitive learning outcomes through post-tests can be seen in Table 7.

Table 7. Categories of Student Learning Outcomes

Average Response Score	Criteria
86-100	Very Good
71-85	Good
56-70	Enough
41-55	Poor
≤ 40	Very Poor

Source: (Basam, 2022)

Inferential analysis is applied to draw various conclusions from sample data. This inferential action includes estimation, forecasting, and decision making based on the relationship between two or more variables (Enterprise, 2014). In this study, inferential analysis is used to test whether the application of fluid e-modules with the PBL model can improve students' motivation and cognitive learning outcomes during the learning process. The data used in this study will be processed using the Multivariate Analysis of Variance (MANOVA) test.

3. Result and Discussion

A. Analysis Stage

At this stage, the researcher collected data, identified, and analyzed data and information regarding student motivation and learning outcomes on fluid material and teaching materials used by students. At this stage, an analysis of teacher and student needs and curriculum analysis were carried out. This analysis was carried out through observation and interviews with teachers and students at SMA Bagan Sinembah using a questionnaire distributed via Google Form. Based on the results of the analysis, it can be concluded that the physics learning process in schools. The use of teaching materials used is printed books available at school, but the printed books available at school are less attractive and boring. In addition, there are few examples of questions in the printed books available at school. In the PBL aspect, 60% of students answered that they strongly agree that students find it easier to understand physics lessons if my teacher relates the material to everyday phenomena/events. In the learning motivation aspect, 76.7% of students answered that they sometimes feel happy when they are going to study physics. In the learning outcome aspect, 63.6% of students answered that they sometimes feel satisfied with their physics learning outcomes.

B. Design Stage

At this stage, the researcher designed the initial e-module by compiling a framework consisting of three main parts: introduction, content, and closing. The opening section includes the cover, identity of the author, supervisor, and validator, instructions for using the e-module, LKPD and practicum, foreword, table of contents, glossary, introduction (containing the identity of the e-module, learning outcomes, learning objective indicators, description of the material, prerequisite concepts, and details of activities), Pancasila student profile, Problem-Based

Learning (PBL) syntax, and concept map. The content section contains fluid material based on PBL syntax, LKPD, quiz questions, and practice questions. Meanwhile, the closing section contains a summary, bibliography, history of the compiler, and explanation of filling out the e-module.

After the initial plan is drawn up, the next step is to choose a theme, layout, and background that are appropriate for the e-module. Then, supporting content is collected such as references from high school and college physics books, images, animations, videos, fluid experiment simulations from PhET Interactive Simulations, as well as quiz applications and practice questions that are relevant to fluid material.

C. Development Stage

The development stage is carried out as a process of finalizing the e-module, conducting revisions, trials and revisions so that results are obtained in the form of comments and suggestions, then a final assessment of the e-module is obtained.

This e-module is structured following the PBL syntax stages, namely: Phase 1 student orientation to the problem This phase presents learning objectives, explains important requirements that must be provided and motivates students to engage in problem-solving activities. This phase contains problems that will be solved by students. Phase 2 organizes students to learn In this phase, the teacher helps students define problems and organize learning tasks related to problems in phase 1. PBL phases 1 and 2 in the e-module can be seen in Figure 2.

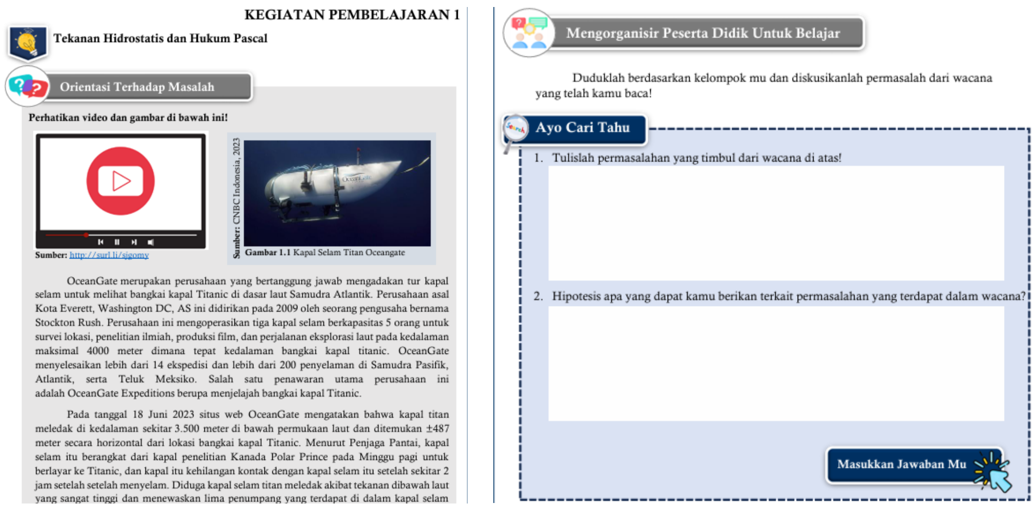

Figure 2. Phase 1 (Orientation Toward the Problem) and Phase 2 (Organizing Students for Learning)

Phase 3 guides individual and group investigations in this phase the teacher encourages students to collect information, appropriate experimental behavior, seek explanations and solutions. In this phase asks students to conduct experiments so that students can answer questions from phase 1. Phase 4 develops and presents the results of the work in this phase the teacher helps students plan and prepare appropriate work such as reports, videos, models, and helps them share their work with other students. Phase 5 analyzes and evaluates the problem-solving process in this phase the teacher helps students to reflect on their investigations and the processes they use. PBL phases 3, 4 and 5 in the e-module can be seen in Figure 3.

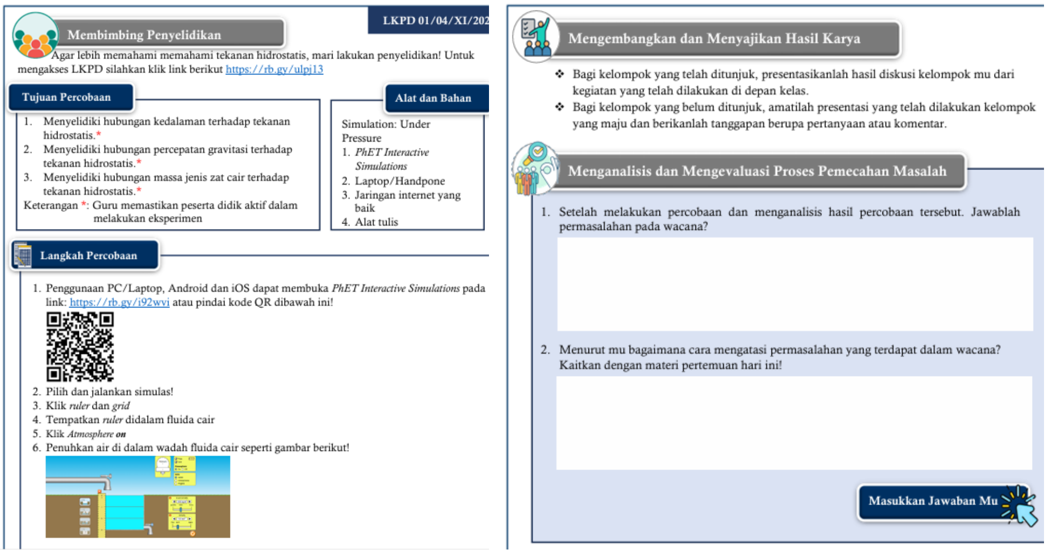

Figure 3. Phase 3 (Guiding Inquiry), Phase 4 (Developing and Presenting Results) and Phase 5 (Analyzing and Evaluating the Problem Solving Process)

a. Validation Results

At this stage the validator gives a value to the instrument given. Expert validators consist of material, pedagogical and media validators. The following are the validation results from the experts presented in Table 8.

Table 8. Results of E-module Validation by Validator

No	Assessment Area	Validation Result Score	
		Average	**Criteria**
1.	Material	3,71	Valid
2.	Pedagogy	3,55	Valid
3.	Media	3,55	Valid
Average Validation Score		**3,60**	**Valid**

The overall validation results in the fields of material, pedagogy, and media in Table 8 show that the fluid e-module using the PBL model is valid with an average of 3.60. This means that the fluid e-module using the PBL learning model that was developed is feasible and can be used in physics learning.

b. Results of small group trials

At this stage, a small group trial was conducted on 3 physics teachers in Pekanbaru and 20 grade XII students at SMAN 8 Pekanbaru. This small group trial aims to improve the procedure for using the product, identify and eliminate errors in using the e-module and obtain information about user reactions, namely students and teachers, to the material and messages from the fluid e-module product using the PBL learning model.

1. Trial Results by Teachers

The teacher response questionnaire consists of 17 questions with 5 assessment aspects assessed using a Likert scale of 1-4. A summary of the assessment by practitioners is shown in Table 9.

Table 9. Trial Result Data by Teachers and Students

Assessment Indicator	Average	Category
Material	3,33	Very Good
Presentation	3,33	Very Good
Language	3,67	Very Good
Design	3,67	Very Good
Benefits	3,33	Very Good
Average	**3,47**	**Very Good**

Based on Table 9, the overall data of the aspects of the trial results to 3 teachers was 3.47 with a very good category. This means that the fluid e-module using the PBL learning model for high school students in grade XI received a very good response from practitioners.

2. Results of Student Trials

The data from the trial assessment results through student response questionnaires assessed using a Likert scale of 1-4 can be seen in Table 10.

Table 10. Student Trial Result Data

Assessment Indicators	Average	Category
Clarity	3,87	Very Good
Ease of Use	3,64	Very Good
Benefits	3,61	Very Good
Attractiveness	3,66	Very Good
Average	**3,70**	**Very Good**

Based on Table 10, it can be seen that the average score of all aspects of the trial results to 20 students is 3.70 with very good criteria. This shows that according to students, the fluid e-module using the PBL learning model is very good for use in schools.

D. Implementation

At the implementation stage in this study is to apply the e-module that has been developed in a real situation in the field, namely in the classroom. This stage is carried out a field trial implementation to students of class XI.1 as an experimental class and students of class XI.4 as a control class at SMAN 4 Bagan Sinembah, Rokan Hilir with the use of fluid e-modules using the PBL model. The trial aims to test the effectiveness of the fluid e-module product using the PBL model on students' motivation and cognitive learning outcomes. To determine the effectiveness of the product developed, students were given a learning motivation questionnaire in the form of statements using a Likert scale of 1-4 as many as 15 statements and posttest questions in the form of multiple-choice cognitive questions from C1-C6 as many as 25 questions.

Research data analysis includes descriptive (describing data systematically to provide an overview) and inferential (drawing conclusions from samples to generalize the population). Detailed explanations of these two analyses will be discussed later.

a. Student Learning Motivation Questionnaire Score

Assessment of students' learning motivation was carried out at the end of the meeting in the experimental class and control class through a questionnaire that had been provided. The questionnaire sheet in this study measured four indicators of learning motivation, namely the desire and desire to succeed, the drive and need to learn, being responsible, and the existence of interesting activities in learning. The description of learning motivation is shown in Table 11.

Table 11. Average Results of Student Learning Motivation

No	Class	Average	Interpretation
1	Experiment	3,47	Very Good
2	Control	2,88	Good

Based on Table 11, it can be seen that the average result of student motivation in the experimental class is 3.47 and the control class is 2.88. These results indicate that after using the fluid e-module with the PBL learning model in the experimental class, the average score was higher than in the control class that did not use the fluid e-module with the PBL learning model. The results of student motivation for each indicator can be seen in Figure 4.

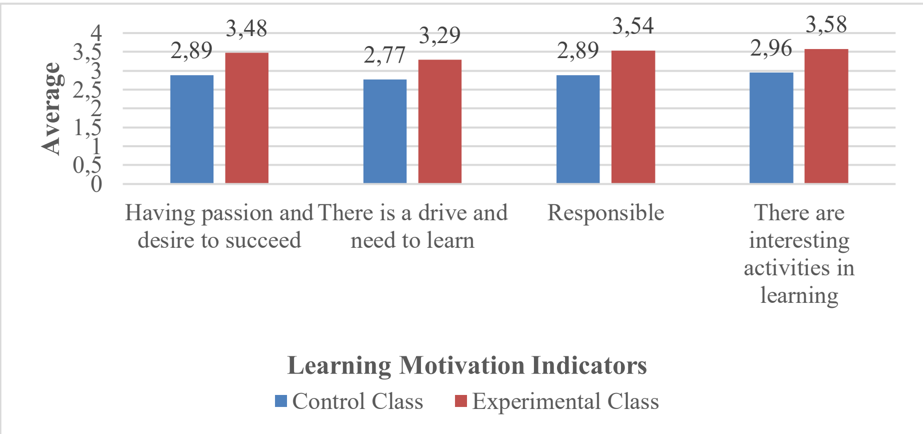

Figure 4. Average Student Motivation for Each Indicator

Figure 4 shows that student motivation after the test has a higher average for each indicator compared to the control class. In line with research conducted by Maghfiroh et al (2024) that the use of e-modules in the learning process accessed through electronic devices is considered to be able to increase student learning motivation so that it affects learning outcomes. In addition, the use of the problem-based learning (PBL) model in the learning process can provide and arouse enthusiasm and motivation to learn so that students are actively involved in learning (Prastiwi & Halidjah, 2024).

b. Post-test Score Cognitive learning test

The cognitive learning outcomes in this study are in the form of formative test results on fluid material. The research data to be analyzed are in the form of learning outcome scores on fluid material in the experimental class and control class. The posttest questions for assessing cognitive abilities are multiple choice questions consisting of 25 with question levels C1, C2, C3, C4, C5 and C6 which are in accordance with the basic competencies and expected competency achievement indicators.

Based on bloom's taxonomy in (Firdaus & Khozin, 2024) said cognitive thinking skills can be categorized into six parts. The revision of the cognitive domain by Anderson and Krathwohl includes the dimensions of remembering, understanding, applying, analyzing, evaluating, and creating. In addition, the level of difficulty of the cognitive level is divided into 3 parts, namely easy, medium and difficult. C1 is included in the easy category, C2 and C3 are included in the medium category and C4, C5 and C6 are included in the difficult category. In making questions, it is necessary to pay attention to the proportion of balanced levels of difficulty, by including questions that vary from different levels of difficulty (difficult, medium, and easy). This is in accordance with Sudjana's opinion in Magdalena et al (2021) that the balance in making questions is the existence of questions that are easy, medium and difficult divided proportionally. The comparison between easy-medium-difficult questions can be made 3-5-2. This means 30% of questions are in the easy category, 50% are in the medium category and 20% are in the difficult category. The description of the results of the posttest of cognitive learning outcomes based on level can be seen in Table 12.

Table 12. Average Score of Cognitive Learning Outcome Posttest

No	Class	Average	Interpretation
1	Experiment	77	Very Good
2	Control	55	Good

Table 12 shows that the average posttest score of the control class is lower with an average of 55 in the low category than the experimental class with an average score of 77 in the good category. The results of student motivation for each indicator can be seen in Figure 5.

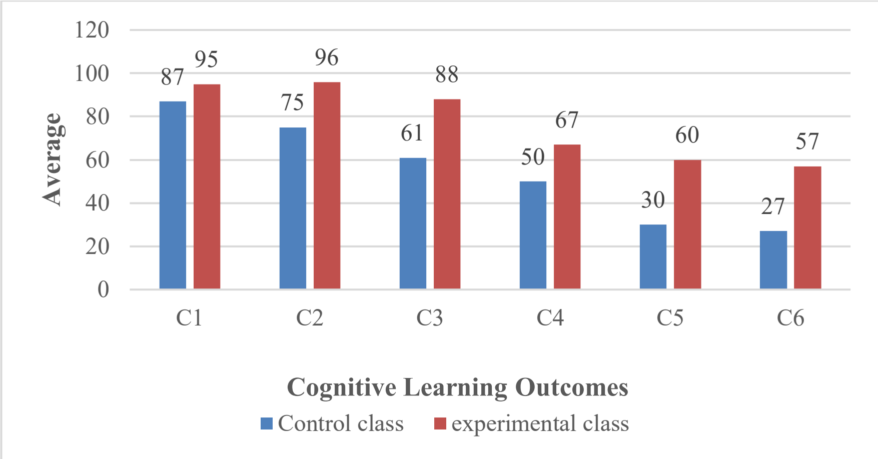

Figure 5. Cognitive Learning Outcome Score Based on Question Level

Figure 5 shows that the cognitive learning outcomes of students in the experimental class got higher scores at each level than the control class. It can be concluded that the application of fluid e-modules using the PBL learning model in the experimental class is better than the control class that does not use e-modules. In line with research conducted by Mahardika et al., (2022) that the use of PBL-based e-modules is quite effective in improving student learning outcomes can be seen from the increase in pre-test and post-test scores.

Inferential Analysis

In addition to descriptive data analysis, this study also conducted inferential analysis related to final decision making. This study first conducted normality tests and homogeneity tests on primary data, namely data on motivation results and students' cognitive learning outcomes. This is because the prerequisite test for inferential statistics in the form of parametric statistics requires that data for samples must be normally distributed.

MANOVA test to show whether there is a significant difference in motivation and learning outcomes of students in the experimental class and the control class. The results of the MANOVA test show that the results of the test of the effects of both independent variables on the dependent variable. The results of the Test of Between-Subjects Effects are shown in Table 13.

Table 13. Results of Test of Between-Subjects Effects

Source	Devendendent Variable	F	Sig.
E-modul	Learning motivation	62.984	<.001
	Cognitive learning outcomes	24.104	<.001

a. R Squared = .529 (Adjusted R Squared = .521)
b. R Squared = .301 (Adjusted R Squared = .288)

The results of Table 13 from the Test of Between-Subjects Effects test obtained significant results on learning motivation <.001, where Sighitung <0.05, then there is a difference in learning motivation of students who use fluid e-modules using the

PBL learning model in learning with those who do not use fluid e-modules using the PBL learning model. While for cognitive learning outcomes, a significance value of <.001 was obtained, where Sighitung <0.05, then there is a significant difference in learning outcomes of students who use fluid e-modules using the PBL learning model in learning with those who do not use fluid e-modules using the PBL learning model.

There is an R squared value on learning motivation and students' cognitive learning outcomes, where the R squared value for learning motivation is 0.529 with a large influence category, which means that the use of fluid e-modules using the PBL learning model influences the increase in learning motivation in classes that use fluid e-modules using the PBL learning model by 52.9% better than those who do not use fluid e-modules using the PBL learning model.

Meanwhile, for cognitive learning outcomes, the R squared value is 0.301 with a large influence category, which means that the use of fluid e-modules using the PBL learning model can affect the increase in students' cognitive learning outcomes by 30.1% better for classes that use fluid e-modules using the PBL learning model compared to classes that do not use fluid e-modules using the PBL learning model. In line with research conducted by (Hartatik, 2022) that the PBL learning model is applied to the student learning environment as a means to facilitate them in learning a concept and constructing their own understanding of the concepts taught. This model encourages students to play an active role during the learning activities with a system of cooperation (group discussions) and cases given by the teacher, so that students feel interested in participating in the learning activities as a whole.

In addition to increasing learning motivation using the PBL learning model can also improve learning outcomes, this is in line with research conducted by (Fadilla et al., 2021) that the use of the PBL model in learning has an impact on improving learning outcomes. The PBL learning model can help students to gain new knowledge, learning experiences, motivate students to learn, improve problem-solving skills and improve critical thinking skills so that they have an impact on the learning outcomes obtained. In addition, the use of the PBL learning model is a learning model that is appropriate for improving cognitive learning outcomes and developing students' scientific attitudes. Because in this learning model, students will be encouraged to be more active in understanding a material through the discovery of their own concepts and knowledge (Aprilia et al., 2023).

E. Evaluation

Evaluation is conducted at each stage of development aimed at the need for product revision. Evaluation is conducted at each stage of development (formative evaluation) and also as a whole (summative). The formative evaluation that has been conducted is in the form of improvements to the fluid e-module using the PBL learning model developed based on validator improvement suggestions at the development stage, small group trial results, and field trial results.

Overall, the development of fluid e-modules using the PBL learning model has followed the development of ADDIE. The results of the analysis stage show that fluid material is one of the materials considered difficult by students. The results of the analysis stage also state that student motivation and learning outcomes are relatively low. Therefore, the development of fluid e-modules using the PBL learning model is needed in physics learning in schools.

4. Conclusion

This study developed a physics e-module based on problem-based learning (PBL) on fluid material with the ADDIE development model (Analysis, Design, Development, Implementation, and Evaluation). The validation results showed that the e-module was valid and very good to be used in physics learning. In addition, this e-module contributed to improving motivation and cognitive learning outcomes of students in the experimental class compared to the control class. It can be concluded that the application of the fluid e-module using the PBL learning model in the experimental class was better than the control class using physics books available at school in improving students' cognitive learning outcomes. Thus, the fluid physics e-module with the PBL model is feasible and effective to be used in learning at school.

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