

# Development of Interactive Physics E-comics Based on Problem-Based Learning to Improve Students' Science Literacy on Fluid

Ummu A'fifah\*, Sri Latifah, and Sodikin

Physics Education Study Program, Faculty of Tarbiyah and Teacher Training, UIN Raden Intan Lampung, Bandar Lampung, Lampung, Indonesia

\* Corresponding author(s), e-mail: [ummuafifah643@gmail.com](mailto:ummuafifah643@gmail.com)

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## Abstract:

Education is a systematic process that aims to transfer knowledge, skills, and values to shape students' character. To support quality education through innovation, this Research and Development (R&D) study aims to develop a Problem-Based Learning (PBL) interactive physics e-comic on fluid materials. Specifically, the study determines the product's feasibility, the responses of educators and students, and its effectiveness in improving students' science literacy. The research utilized the ADDIE model, comprising analysis, design, development, implementation, and evaluation stages. The validation results indicated that the e-comic is highly feasible, achieving average scores of 89.40% from material experts, 78% from media experts, and 91.67% from learning instrument experts. Furthermore, the product garnered a "very interesting" response rate of 95% from educators and 91.49% from students. The effectiveness test revealed an N-Gain score of 0.76 (high category), demonstrating a significant improvement in students' science literacy. Based on these findings, it can be concluded that the PBL-based interactive physics e-comic is highly feasible, engaging, and effective to be used as a learning medium.

## 1. Introduction

Education is a systematic process that aims to transfer knowledge, skills, and values to students' character. Every individual has the right to receive education; therefore, the government must develop innovations and new ideas to provide quality education (Fadhillah et al., 2024). The learning process plays a crucial role in improving the quality of education as a whole and preparing future generations to face global challenges. The goal is not just to transfer knowledge, but to form human resources who are qualified, innovative, and wise in utilizing technology. Through Education, students are equipped with scientific understanding and skills to handle complex tasks in the future. One of the must-have skills in education is science literacy skills (Usman et al., 2024).

Science literacy is defined as the ability to engage with science-related issues and the ideas of science as a reflective society. Developing this competence is essential; students equipped with science literacy skills can effectively apply their knowledge to solve real-world problems in daily life situations (Prihatiningtyas et al., 2025). However, the results of international assessments show that the ability of students in Indonesia is below the data standards set (Nob et al., 2025).

Based on the average score of the Program for International Student Assessment (PISA) from the Organization for Economic Co-operation and Development (OECD) survey, in 2018, Indonesia ranked 70th out of a total of 78 participating countries, with an average score of 396 (OECD 2019). In the next PISA evaluation in 2022, Indonesia's position increased to 56th out of 81 participating countries, although its average score actually decreased to 383 (OECD 2022). This reflects the low quality of education, especially in terms of science literacy skills in Indonesia (Pamei et al., 2023)

The role of teachers in utilizing science and technology (IPTEK) also has a positive impact on students' learning achievement (Tria Rahayu et al., 2023). However, in its implementation, teachers still have obstacles in the use of conventional teaching materials and school facilities that are still inadequate. This condition causes students to be less actively involved in the learning process and have difficulty relating science concepts to concrete experiences in daily life. Several studies have confirmed that learning that is still teacher-centered, lacking innovative media, and lacking contextualized is one of the causes of students' weak mastery of science literacy (Permanasari et al., 2022; Siregar & Siregar, 2024).

To overcome this, learning media is needed as a bridge that explains and makes it easier for students to understand the material that will be delivered in learning. Interactive and interesting learning media to increase student involvement in the learning process (Lim Halimatul Mu'minah, 2021). The right media can make it easier for students to understand abstract material, especially in physics learning, which is often difficult for students to understand due to the complex nature of the material. Learning Media that is able to visualize physics concepts while presenting real problems so that students can build an active understanding. Therefore, it is important to present innovative learning media to facilitate a more effective learning process (Dafit & Mustika, 2021).

One of the learning media that can be used is the development of electronic comic-based learning media (e-comic) (Baifeto et al., 2022), a digital interactive media that can present physics concepts through visual storytelling. This media is designed to help students understand abstract concepts more easily through a combination of text, images, and contextual narratives (Murni et al., 2025). Compared to e-LKPD and e-modules, which generally emphasize the presentation of material and practice questions in a linear manner, e-comics are more effective in presenting problems as the initial focus of learning. This media is a learning system to eliminate boredom and increase students' enthusiasm for learning. Along with the development of technology, comics are not only in the form of print media but also digital. Technology that is developing so rapidly has made digital media a new medium to produce and disseminate comics. Therefore, the development of e-comic media is very suitable for use in learning, especially in the development of the millennial era or the current 21st century (Feronika Kurnia Septiarni, 2023).

The Problem-Based Learning (PBL) model is one of the learning models that builds students' science literacy. A learning model that provides opportunities for students to discover their own knowledge and play an active role in learning so that they are able to understand concepts well and develop their science literacy skills (Tri et al., 2023). So that in physics learning, this model is very effective because it allows students to understand concepts such as fluids through the process of investigation and exploration independently.

The development of e-comics in learning has been integrated into learning models such as contextual (Shahwa et al., 2024), local wisdom (Sari et al., 2020), and applied in the subject matter, such as in the Measurement material (Rendi et al., 2020), Pressure (Setiani et al., 2021), Newton (Baifeto et al., 2022). In addition, it has been applied on digital platforms such as Instagram (Bahri & Supardi, 2022). However, these studies move on different intervention paths. There has not been a dominant research that specifically develops interactive physics e-comics based on PBL on fluid topics that are directly oriented towards improving students' science literacy. In other words, there are empirical gaps and media design gaps that are still not adequately filled.

Based on these conditions, the research gap in this study is explained in three aspects. First, there is a substantial gap, namely the low science literacy of students, that has not been completely overcome

through learning in fluid materials. Second, there is a media gap, which is that the benefits of audiovisual-narrative media that are in accordance with students' cognitive characteristics are not optimal to support learning in fluid materials. Third, there is a gap in previous research, namely although there has been research on e-comic learning media, there are still limited studies that develop interactive physics e-comics based on PBL on fluid topics which are explicitly directed to improve students' science literacy, especially in fluid materials.

Based on this description, this research aims to develop an interactive physics e-comic on fluid topics using PBL that is feasible, engaging, and effective in improving students' science literacy. Thus, the problem formulation in this study is to develop an interactive physics e-comic based on PBL on fluid topics that is feasible, interesting, and effective in improving students' science literacy.

## 2. Theoretical Framework

### 2.1. E-Comic Learning Media

The word media in "learning media" comes from the Latin word *medius*, which means 'middle', 'intermediary,' or 'introduction'. Learning media in general is a tool for the teaching and learning process. Everything that can be used to stimulate thoughts, feelings, attention, and learning abilities or skills can encourage the learning process (Sidik, 2023).

The National Education Association (NEA) defines media as any object that can be manipulated, seen, heard, read, or talked about, along with the instruments used for these activities (Septy Nurfadhillah, 2021). Learning media can also be interpreted as a tool used by teachers in the learning process to help convey learning messages in all forms, either in the form of materials or events that build certain conditions as an intermediary in the teaching and learning process to achieve a learning goal that has benefits, namely being able to clarify the message so that it is not too verbalistic, overcoming limitations, providing stimulation, which can equalize understanding and can provide effective and efficient learning (Arifannisa, 2023).

The function of learning media is to create conditions for students to capture knowledge accurately and deeply, develop cognitive capacity, and shape students' personalities. The types of learning media are; auditory media, visual media, audio-visual media, audio media, motion media, and computer media (M. Miftah Arief, 2021).

Learning media on fluid materials is arranged by emphasizing visual representation, interactivity, and presentation of contextual problems simultaneously. Fluid materials have abstract and dynamic characteristics, so that students often have difficulty understanding concepts if learning is only conveyed through text and mathematical equations. Research shows that the use of interactive multimedia in fluid materials can help improve students' understanding of concepts because visualization is able to clarify physical phenomena that are difficult to observe directly (Hermansyah et al., 2022).

Comics are illustrated stories consisting of reading texts and short dialogues, which will certainly make it easier for readers to understand a story. Comics can also be defined as a form of cartoon that expresses characters and acts out a story in a sequence that is closely linked to images and designed to provide entertainment to readers (Ardani, 2023).

The purpose of comics is as a learning medium that can increase students' involvement and motivation in learning science, especially in fluid materials. This helps students to be more active in participating in learning and understanding the material presented. The types of comics are as follows (Maharsi & Pamungkas, 2011):

- a) Cartoon

Cartoons that only have one look and several images that end in writing.

b) Comic Book

The collection of pictures, writings and stories is packaged in the form of a book (there is a cover and contents).

c) Comic Strip

This form of comics is only in the form of fragments of images that are arranged/assembled into a short storyline.

d) Comic Annual

Comics published regularly or on a scale.

e) Web Comic

Comics that are packaged in online form.

This interactive physics e-comic is included in the type of web comics, which are comics that are published online through websites or mobile applications. The selection of the type of web comic is based on its excellence in integrating visual, text, and digital technology elements in a single medium that is easily accessible through electronic devices. Compared to print comics, web comics have a higher flexibility of use because they can be accessed anytime and anywhere, and are able to present a more interactive display (Wulandari & Widodo, 2024).

E-comics are a medium that is simple, easy, and clear. The use of e-comics as a learning medium has a very important role, because its presentation is able to bring students into a fun atmosphere. One of the physics materials that can be used in e-comic media is Fluida (Arini et al., 2022).

## 2.2. Problem Based Learning

Problem-Based Learning (PBL) was developed by Howard Barrows in learning at *Southern Illinois University School of Medicine* (Barrows, 1986). PBL is a learning model that always helps students learn. Students gain critical thinking skills, improve literacy, improve problem-solving skills, and develop their own knowledge through PBL (Nurhayati et al., 2023).

PBL model consists of 5 stages, namely: orientation of students to problems, organizing students, guiding individual or group investigations, developing and presenting results, and analysing and evaluating the results of problem solving (Syarifah, 2022). The main goal of PBL is to help students develop their ability to solve complex and real-world problems.

In physics learning, the PBL model is more effectively applied to materials that are related to everyday life phenomena. One of the materials that has been applied in the PBL model is integrated into subjects such as business and energy (Nabila, 2024) because it is able to present contextual problems that are close to the students' experience.

## 2.3. Science Literacy

Science literacy comes from two combinations of Latin words, namely *litteratus* and *scientia*. The word *litteratus* means literate, educated, while *scientia* means having knowledge. Science literacy is a person's ability to understand science, communicate, apply it in daily life, and can also overcome problems in daily life with the concept of science (Toharudin, 2011).

The science literacy indicators used in this study are based on PISA 2022 science literacy, which is the domain of knowledge and competency assessment, while the indicators of science literacy applied in this research are presented in Table 1 (OECD, 2023).

**Table 1.** *Science Literacy Indicators*

No.	Science Literacy Indicators	Science Literacy Sub-Indicators
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1. Explain the phenomenon scientifically	Remember and explain scientific phenomena with the ability to implement appropriate scientific knowledge. Identifying, using, and generating models and representing them. Make and correct the right predictions.
2. Evaluate and design scientific investigations	Identify questions explored in scientific studies. Explain and assess the various methods used by scientists to verify the accuracy and objectivity of the data.
3. Interpreting data and evidence scientifically	Converts data from one representation to another. Analyze, interpret, and draw conclusions from data. Identify assumptions, evidence, and reasoning in science texts.

Several previous studies have adopted the PISA science literacy indicator as a basis for developing instruments and measuring students' science literacy. The use of PISA indicators is one of the references that are widely used in science education research. One of the studies that applies this indicator is about the analysis of students in solving science problems (Zahro et al., 2025).

### 3. Method

This research uses the type of Research and Development (R&D). R&D is a research method used to design, realize, and test the effectiveness of e-comics. To obtain the results of e-comics, research is used in the nature of needs analysis and tests the effectiveness and feasibility of e-comics developed so that they can function in the wider community.

This development research model uses the ADDIE model. This model was chosen because of its suitability for creating and evaluating fluid material in the form of e-comics based on PBL. With evaluation at each stage, it can minimize level errors and product shortcomings in the final stage of the ADDIE model. This model consists of five steps or stages, namely: Analysis, Design, Development, Implementation, and Evaluation.

Here is a picture of the stages of development of the ADDIE model.

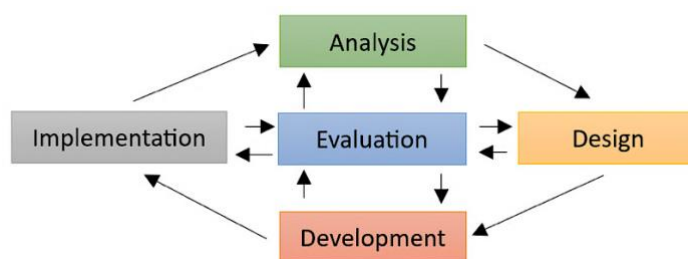


Figure 1. Stages of ADDIE model development.

#### 3.1. Analysis

Analysis is the first stage contained in the ADDIE model. At this stage, the process of problem identification and needs analysis is carried out. Identify problems by conducting pre-research at SMA Negeri 1 Bandar Lampung and MAN 1 Bandar Lampung. Data collection is carried out differently from school to school, namely at SMA Negeri 1 from class XI. F.3 and at MAN 1, data were taken from class XI. 1.7. Data was collected through interviews with one physics teacher in each school to identify the needs of educators in the learning process. Students were given science literacy test questions to determine the level of initial science literacy ability. The questions were given to 15 students in each school. Then, analyze the needs of students by providing a questionnaire of 7 questions. After that, the

data is analyzed descriptively to determine the learning needs of students and educators, and to determine the initial literacy level. The student needs analysis questionnaire consisted of seven closed-ended questions with Yes/No response options, as shown in Table 2.

**Table 2.** *Student Needs Analysis Question Item*

No	Questions
1.	Do you study physics independently at home?
2.	Are you happy and interested in physics lessons?
3.	Were you given a book from school to study physics?
4.	Are you looking for other media besides books from schools to help you understand a material? (e.g. via PPT, video)
5.	Do you have difficulty learning fluid materials through teaching media and methods applied by teachers?
6.	Do you think fluid material will be easier to understand if you use interactive teaching media based on problem-based learning and daily life?
7.	Do you agree that alternative teaching media in the form of Problem Based Learning-based interactive physics E-comic should be developed to improve science literacy in students' fluid materials so that the material is more

Meanwhile, the teacher's needs analysis was conducted through interviews consisting of ten questions, as shown in Table 3.

**Table 3.** *Teacher Needs Analysis Question Item*

No	Questions
1.	What is the curriculum used in this school?
2.	What is the interest of students in physics subjects?
3.	How curious are students about E-Comic media on fluid materials?
4.	Do you already have teaching media that is in accordance with the Merdeka curriculum? (PPT and LKPD)
5.	Do you think fluid material is a difficult material for students when viewed from the students' learning results in the
6.	Do you encounter any limitations in the handbook?
7.	Do you use special teaching media to support the learning process in fluid materials?
8.	Have you ever used teaching media based on the Problem Based Learning model?
9.	Do you need an interactive Problem Based Learning model-based teaching media to help the learning process be
10.	Do you agree if teaching media in the form of Problem-Based Learning-Based Interactive Physics E-Comic is

The distribution of questionnaires and interviews was carried out through google forms and face-to-face, so that researchers obtained research data as a supporting sample for research that in schools there is a need for the development of interactive physics e-comic media based on PBL to improve science literacy in students' fluid materials.

### 3.2. Design

At this stage, the researcher designed an interactive physics e-comic by integrating the PBL model with science literacy indicators.

**Table 4.** *Design Stages Table*

No.	Story Topics	Fluid Concept	Science Literacy Aspects
1.	"Water Pools on Sloping Surfaces"	Hydrostatic Pressure	Explaining Phenomena Scientifically
2.	"Perforated Bottle"	Hydrostatic Pressure	Evaluating and Designing Scientific Investigations
3.	"The Secret of Encouragement from Underwater"	Archimedes' Law	Explaining Phenomena Scientifically
4.	"Relationship of Density and Surface Stress in Floating Phenomena"	Density, Archimedes' Law and Surface	Explaining Phenomena Scientifically
5.	"The Secret Behind the Waterway"	Continuity and Bernoulli equations	Interpreting the Relationship of Pressure, Velocity and Cross-Section Area

The design focused on developing teaching materials that present fluid mechanics concepts through contextual stories and problem situations. The product design process involved determining the

specifications of the e-comic, including the story topics, fluid concepts, and the science literacy aspects incorporated into each storyline. The design stages and content specifications of the developed e-comic are presented in Table 4.

### *3.3. Development*

The third stage is the development stage, in which the designed e-comic is developed into a complete learning medium. This stage includes expert validation to evaluate the quality and feasibility of the developed e-comic. The validation process involved two material experts, two media experts, and two experts in learning and test instruments. In addition to expert validation, questionnaires were distributed to students and teachers to obtain their responses regarding the attractiveness and acceptance of the developed e-comic. After the validation process was completed, revisions were made based on the feedback, suggestions, and assessment notes provided by the validators. These revisions were intended to address identified weaknesses and improve the quality of the product before its implementation..

### *3.4. Implementation*

The implementation stage was carried out to test the effectiveness of the interactive physics e-comic based on PBL that has been developed. The implementation was carried out on 67 students in class XI at SMA Negeri 1 Bandar Lampung and MAN 1 Bandar Lampung. Before learning starts, students are given a pretest to find out their initial science literacy skills. Furthermore, learning was carried out using an interactive physics e-comic based on PBL during two meetings.

The use of e-comics is adjusted to the PBL syntax. At the problem orientation stage, students observe contextual problems presented in the e-comic. At the stage of organizing students, teachers guide the formation of discussion groups. Furthermore, students conduct investigations to find solutions to the problems given. The results of the investigation were then presented and discussed together. In the final stage, students reflect on the problem-solving process that has been carried out.

After the learning activities were completed, students were administered a post-test to measure changes in their science literacy. The pre-test and post-test scores were analyzed using the N-Gain score to determine the effectiveness of the developed interactive physics e-comic in improving students' science literacy.

### *3.5. Evaluation*

At this stage, an evaluation was conducted to determine whether the developed interactive physics e-comic met its intended objectives. The evaluation involved assessments by experts in relevant fields, followed by revisions based on their feedback. In addition, a summative evaluation was conducted after the PBL interactive physics e-comic had been successfully implemented.

The participants in this development research were Grade XI high school students (Phase F) from two schools in Bandar Lampung. One class from each school was selected as the research sample, resulting in a total of approximately 67 students. The research instruments consisted of non-test instruments, namely interviews and questionnaires.

Product testing was conducted after the completion of the product design and was intended to collect data that could be used to determine the product's effectiveness, efficiency, and attractiveness. The testing process included both small-group and field trials. The small-group trial involved 5–10 students, who were asked to complete a questionnaire consisting of several evaluation criteria and questions. The field trial was conducted with all participants, who served as respondents.

Students' science literacy skills were assessed using a 10-item multiple-choice test, the details of which can be found in Appendix A (Table 19). The resulting data were analyzed through validity, reliability, discrimination, and difficulty index tests. Non-test data were analyzed using qualitative descriptive techniques. The analyzed data were obtained from expert validators, including material experts, media experts, and PBL experts, as well as from educators' and students' responses to the PBL interactive physics e-comic. The non-test instrument was a Likert-scale questionnaire used to measure individuals' or groups' attitudes, opinions, and perceptions regarding a particular social phenomenon.

### 3.6. Expert Validation Questionnaire Analysis

The final score of each item was calculated as the percentage of the average indicator score across all validator ratings. The average indicator score was computed as  $\bar{x} = \Sigma x/n$ , where  $\bar{x}$  denotes the mean score,  $\Sigma x$  is the sum of all validator scores for the indicator, and  $n$  is the number of validator responses. The eligibility percentage was then calculated as  $(S_{obt}/S_{max}) \times 100\%$ , where  $S_{obt}$  represents the obtained score and  $S_{max}$  represents the maximum possible score. The interpretation of validation scores was based on the feasibility criteria proposed by Arikunto (2021) as presented in Table 5.

**Table 5.** Validation Criteria

Interval	Criteria
$80\% < \bar{x} \leq 100\%$	Highly Feasible
$60\% < \bar{x} \leq 80\%$	Feasible
$40\% < \bar{x} \leq 60\%$	Moderately Feasible
$20\% < \bar{x} \leq 40\%$	Less Feasible
$0\% < \bar{x} \leq 20\%$	Not Feasible

### 3.7. Response Questionnaire of Educators and Students

To evaluate the responses of both educators and students, this study utilized a five-point Likert scale administered via a checklist. The scale ranges from 1 to 5. This measurement technique was selected due to its systematic approach and clarity in quantifying participant feedback. The scoring criteria for individual responses are detailed in Table 6 (Yuberti and Antomi Saregar, 2020), while the overall attractiveness criteria, calculated based on percentage intervals, are presented in Table 7 (Sugiyono, 2022).

**Table 6.** Response Based on the Likert Scale

Score	Criteria
5	Very Interesting
4	Interesting
3	Moderately Interesting
2	Slightly Interesting
1	Not interesting

**Table 7.** Attractiveness Criteria

Interval	Criteria
$80\% < \bar{x} \leq 100\%$	Very Interesting
$60\% < \bar{x} \leq 80\%$	Interesting
$40\% < \bar{x} \leq 60\%$	Moderately Interesting
$20\% < \bar{x} \leq 40\%$	Slightly Interesting
$0\% < \bar{x} \leq 20\%$	Not Unattractive

### 3.8. Science Literacy Ability Analysis

The improvement in students' scientific literacy abilities was quantified using the Normalized Gain (N-Gain) score. The N-Gain is calculated using the formula  $N - Gain = \frac{\text{post test score} - \text{pre test score}}{\text{maximum value} - \text{pretest value}}$ .

Once calculated, the N-Gain values are classified into three distinct categories to determine the magnitude of improvement. These categorization criteria are outlined in Table 8.

**Table 8.** *N-Gain Score Range*

N-Gain Value	Criteria
$G \geq 0,7$	High
$0,31 \leq G < 0,7$	Medium
$G < 0,3$	Low

## 4. Result

Research and Development (R&D) conducted by the researcher produced an interactive physics e-comic, based on Problem-Based Learning (PBL), to improve students' science literacy. The development of R&D in this study follows several systematic stages: analysis, design, development, implementation, and evaluation. The stages in developing an interactive physics e-comic by the researcher are explained through the following stages:

### 4.1. Analysis

Based on interviews with educators, it is known that the learning media they use still tend to be monotonous, namely in the form of packaged books, LKPD, and PPT. This certainly has an impact on students who quickly feel bored because the teaching media used is less varied.




Based on the results of the pre-research, the results of the science literacy test show that the average score of students is 57%, with a low category. This condition is shown by the low ability of students to explain scientific phenomena, interpret data, and connect physics concepts with problems in daily life. One of the factors that is suspected to affect this condition is the learning process that still focuses on delivering concepts and solving problems theoretically, so that students tend to memorize the material without understanding its application in a real context. In addition, the use of learning media that is still limited and less varied causes students to be less actively involved in the learning process. As a result, learning has not been fully able to facilitate the development of science literacy that emphasizes scientific thinking skills, problem-solving, and decision-making based on scientific evidence.



The results of the analysis of students' needs show that learning activities in the classroom have not used teaching media in the form of an interactive physics e-comic. So that students' understanding of science literacy in physics lessons, especially in fluid materials, is still relatively low. Based on the analysis of the needs questionnaire, students prefer interesting learning media such as images, videos, or animations. This is because the existing learning media do not fully help students in understanding physics lessons, especially fluid materials.

### 4.2. Design

The design phase comprises the visual and pedagogical conceptualization of the learning media. During this stage, the interactive physics e-comic was storyboarded and developed to closely align with both the PBL model and the targeted scientific literacy indicators. Representative visual layouts of the e-comic at various learning stages are presented in Table 9.

Table 9. E-comic Stage Display

No	Story Topics	Reasons for Choosing Illustrations	Fluid Concept	Science Literacy Aspects
1.		It was chosen because it is close to the learner's experience and is able to visualize changes in pressure to depth.	Hydrostatic Pressure	Explain Phenomena Scientific
2.		Because it is a simple phenomenon that can be observed in daily life	Hydrostatic Pressure	Evaluate and Designing Research Scientific
3.		Because it is able to directly show the existence of an upward force felt when the object is dipped.	Archimedes' Law	Explain Phenomena Scientific

No	Story Topics	Reasons for Choosing Illustrations	Fluid Concept	Science Literacy Aspects
4.		Because to display phenomena that are often considered contrary to the initial understanding of students.	Density, Archimedes' Law and Surface Stress	Explain Phenomena Scientific
5.		Because it has a direct relationship with environmental problems that are close to daily life.	Continuity and Bernoulli equations	Interpret Relationships Pressure, Speed and Cross-Section Area

### 4.3. Development

#### 1) Subject Matter Expert Validation

The feasibility of the developed e-comic's content was evaluated by subject matter experts across five primary aspects. The quantitative assessment results are summarized in Table 10.

**Table 10.** Table of Material Expert Validation Results

No.	Aspects	Percentage	Criteria
1.	Content Eligibility	84,61%	Highly Feasible
2.	Language Qualifications	86,66%	Highly Feasible
3.	Presentation Eligibility	85,71%	Highly Feasible
4.	PBL Assessment Eligibility	90%	Highly Feasible
5.	Science Literacy Assessment Qualifications	100%	Highly Feasible
	Average	89,40%	Highly Feasible

Based on the assessment results from the validation by material experts, the feasibility aspect received a score of 84.61% under the 'very feasible' criterion. In the second aspect, namely the feasibility aspect of Language, it received a percentage score of 86.66% with the criterion of 'very feasible'. In the third aspect, namely the feasibility aspect of the presentation, it received a percentage value of 85.71% with the criterion of 'very feasible'. In the fourth aspect, namely the feasibility aspect of the PBL

assessment, it received a percentage score of 90% with the criterion of 'very feasible'. And in the fifth aspect, namely the feasibility aspect of the science literacy assessment, received a percentage score of 100% with the criterion of 'very feasible'. The average assessment results conducted by the team of material expert validators regarding the feasibility of the material presented received a percentage of 89.40% with the criterion of 'very feasible'.

In addition to quantitative scores, the subject matter experts provided qualitative feedback to guide further revisions of the e-comic. The specific recommendations provided by the validators, along with the corresponding corrective actions taken during the revision phase, are detailed in Table 11.

**Table 11.** *Subject Matter Expert Validation Suggestions and Improvements Table*

Validator	Suggestions	Improvement
Validator 1	<ol style="list-style-type: none"> <li>1. Fix the discussion conversation on page 14.</li> <li>2. Add an explanation of fluid matter to each theory.</li> </ol>	<ol style="list-style-type: none"> <li>1. The discussion conversation on page 14 has been fixed.</li> <li>2. Addition of an explanation of fluid matter to each theory.</li> </ol>
Validator 2	<ol style="list-style-type: none"> <li>1. Adjust the learning indicators to the current curriculum.</li> <li>2. Explain the concept of physics in the correct sentences or terms.</li> <li>3. Add an explanation of the formula to each theory.</li> <li>4. Adjust the order of the material from the static fluid and after that the dynamic fluid.</li> <li>5. Explain the definition of fluid correctly in the supplementary material menu.</li> </ol>	<ol style="list-style-type: none"> <li>1. The learning indicators have been adjusted to the current curriculum.</li> <li>2. The explanation of the concept of physics has been explained using the correct sentences or terms.</li> <li>3. An explanation of the formula for each theory has been added.</li> <li>4. The material is already sorted from static fluid to dynamic fluid.</li> <li>5. A precise definition of fluid has been explained in the supplementary material menu.</li> </ol>

## 2) Media Expert Validation

Following the evaluation of the subject matter, the visual and structural components of the e-comic were assessed by media experts. The results of this validation phase are outlined in Table 12.

**Table 12.** *Table of Media Expert Validation Results*

No.	Aspects	Percentage	Criteria
1.	Comics Size	80%	Feasible
2.	Comic Cover Design	74,28%	Feasible
3.	Comic Content Design	80,55%	Highly Feasible
	Average	78%	Feasible

Based on the table of assessment results obtained from the validation of media experts above, it can be seen that in the aspect of comic size, a percentage value of 80% was obtained with the criterion of 'feasible'. In the second aspect, namely the design aspect of the comic cover, a percentage value of 74.28% was obtained with the criterion of 'feasible'. And in the third aspect, namely the design aspect of the comic content, a percentage value of 80.55% was obtained with the criterion of 'very feasible'. The average assessment results conducted by the media expert validator team regarding the feasibility of the content presented received a percentage of 78% with the criterion of 'feasible'.

In addition to the quantitative scores, the media experts provided qualitative feedback to further refine the e-comic's design. The validators' suggestions and the corresponding revisions implemented are outlined in Table 13.

**Table 13.** *Media Expert Validation Suggestions and Improvements Table*

Validator	Suggestions	Improvement
Validator 1	The appearance of the cover is still not firm, too plain and the choice of typeface is still not good.	1. The appearance of the cover has been fixed and the font selection has been changed.

	Add a description of the content in the conversation as well as the formula used (using Scientist language). Pay attention to the use of appropriate colors, if you use soft colors, try to be consistent.	2. Explanation of content in conversation and formula writing using Scientist's Language has been added to the e-comic-based material menu. 3. The appearance of the type of color has been improved with consistency using soft colors.
Validator 2	Pay attention to the selection of color types on the learning evaluation menu, try to choose bright colors.	The selection of color types on the learning evaluation menu has been improved by choosing light colors.

### 3) Media Expert Validation of Learning Instruments and Test

The evaluation of the learning instruments and test questions was conducted by instrument validators to ensure structural and content validity. The quantitative validation outcomes are summarized in Table 14. The detailed item-by-item scoring results are summarized in Appendix B (Table 20).

**Table 14.** *Table of Validation Results for Learning Instruments and Tests*

No.	Aspects	Percentage	Criteria
1.	Contents	100%	Highly Feasible
2.	Construction	87,5%	Highly Feasible
3.	Language	87,5%	Highly Feasible
	Average	91,67%	Highly Feasible

Based on the table of assessment results obtained from the expert validation of learning instruments and tests above, it can be seen that in the aspect of content (content) a percentage value of 100% was obtained with the criterion of 'highly feasible'. In the second aspect, namely the construction aspect, a percentage value of 87.5% was obtained with the criterion of 'very feasible'. And in the third aspect, namely the language aspect, a percentage value of 87.5% was obtained with the criterion of 'highly feasible'. The average assessment results conducted by the instrument expert validator team and test regarding the feasibility of the questions to be given received a percentage of 91.67% with the criterion of 'highly feasible'.

Qualitative recommendations provided by the validation team for refining the learning instruments and tests are detailed in Table 15.

**Table 15.** *Suggestions and Improvements for Expert Validation of Learning Instruments and Tests*

Validator	Suggestions	Revisions
Validator 1	1. Use appropriate physics terminology (deep-shallow; big-small) 2. Fix the symbols on the manometer image	1. Physics terms (deep-shallow; large) have been corrected appropriately. 2. The symbol on the manometer image has been corrected, which can be seen in question number 10.
Validator 2	No suggestion suggested	No revision

### 4) Student Response Questionnaire on Small Group Trial

Following the expert validation phase, a small group trial was conducted to gauge preliminary student responses to the interactive physics e-comic. The evaluation encompassed four primary domains: material, language, relevance, and the integration of PBL and science literacy. The quantitative outcomes of this trial are presented in Table 16.

**Table 16.** *Small Group Trial Results Table*

No	Aspects	Percentage	Criteria
1.	Material	98.33%	Very Interesting
2.	Language	96.66%	Very Interesting
3.	Relevance	98.28%	Very Interesting
4.	PBL and Science Literacy	97.50%	Very Interesting
	Average	97.69%	Very Interesting

Based on the results of small group trials presented in the table above, it is known that the material aspect received a percentage assessment of 98.33% with the criterion of 'very interesting', in the language aspect it obtained a percentage value of 96.66% with the criterion of 'very interesting', the relationship aspect obtained a percentage value of 98.28% with the criteria of 'very interesting' and in the aspect of PBL and science literacy obtained 'The percentage value is 97.50% with the criterion of 'very attractive'. The average assessment results carried out at the small group trial stage of the interactive physics e-comic developed received a final percentage score of 97.69% with the criterion of 'very interesting'.

#### 5) Student Response Questionnaire on Field Trial

To validate the findings from the small group trial on a larger scale, a comprehensive field test was subsequently administered. The student responses collected during this broader implementation phase are detailed in Table 17.

**Table 17.** *Table of Field Test Results*

No	Aspects	Percentage	Criteria
1.	Material	91.09%	Very Interesting
2.	Language	91.14%	Very Interesting
3.	Relevance	91.94%	Very Interesting
4.	PBL and Science Literacy	91.79%	Very Interesting
	Average	91.49%	Very Interesting

The table above explains the results of the response test of students, it is known that the material aspect obtained a percentage value of 91.09%, in the language aspect obtained a percentage value of 91.14%, in the related aspect obtained a percentage value of 91.94%. And in the aspect PBL and science literacy, it obtained a percentage score of 91.79%. From the table above, it can be seen that the average of the four aspects of the assessment is 91.49% which is included in the 'very interesting' category.

#### 6) Educator Response Questionnaire on Field Trial

In addition to student feedback, educator responses were collected during the field trial to evaluate the practicality and instructional value of the developed e-comic from a pedagogical perspective. The results of the educator response assessment are presented in Table 18.

**Table 18.** *Table of Educator Response Results*

No	Aspects	Percentage	Criteria
1.	Difficulties with Student Development Levels	96%	Very Interesting
2.	Communicative	95%	Very Interesting
3.	Serving Techniques	93,33%	Very Interesting
	Average	95%	Very Interesting

The table above explains the results of the educator response test, it is known that the difficulty aspect with the level of development of students obtained a percentage value of 96%, in the communicative aspect obtained a percentage value of 95%, and in the aspect of presentation techniques obtained a percentage value of 93.33%. From the table above, it can be seen that the average of the three aspects of the assessment is 95% which is included in the 'very interesting' category.

### 4.4. Implementation

The implementation of interactive physics e-comic based on Problem Based Learning took place during two meetings involving 67 students. During the learning process, learners actively discuss in groups to identify and solve problems presented in the e-comic. Teachers act as facilitators who guide the process of discussion and investigation of students.

The results of the pretest and posttest analysis showed an increase in students' science literacy after using interactive physics e-comic based on Problem Based Learning. The average pretest score of 52.08

increased to 89.10 in the posttest. Based on the calculation of N-Gain, a value of 0.76 was obtained included in the high category with the calculation of N-gain in each indicator, namely explaining the phenomenon scientifically getting a percentage of 0.84, evaluating and designing scientific investigations getting a percentage of 0.75 and interpreting data and scientific evidence getting a percentage of 0.69.

#### 4.5. Evaluation

The final stage of the ADDIE development model is in the evaluation stage. The evaluation carried out by the researcher by analyzing the data of the research results that had been obtained, including the validation analysis of material experts, media experts and learning instrument experts and tests from 6 validators, namely lecturers. Furthermore, the analysis of attractiveness by educators and students as well as the analysis of the effectiveness of increasing students' science literacy. Because the evaluation stage has been carried out from each stage, the final results show that the interactive physics e-comic based on PBL to improve science literacy is very feasible, very interesting, and has an increase in science literacy with high criteria and is ready to be used as a learning medium for class XI Phase F at SMA Negeri 1 Bandar Lampung and MAN 1 Bandar Lampung.

### 5. Discussion

#### 5.1. Interpretation of Findings

The findings of this study show that the use of interactive physics e-comic based on Problem Based Learning on fluid materials has a positive influence on improving students' science literacy. Students show better ability to understand fluid concepts, connect physical phenomena with daily life, and analyze scientific problems contextually. These findings are in line with research on the development of HOTS-based physics comics which show that comics are able to help physics concepts more effectively and improve higher-level thinking skills (Rofi'ah & Kholiq, 2022).

In the learning process, interactive e-comics provide a more interesting learning experience than conventional media. Visualization of images, storylines, and presentation of contextual problems make it easier for students to understand abstract concepts such as hydrostatic pressure, Pascal's law and Archimedes' law. The use of the PBL model also helps learners to not only memorize formulas, but to be able to identify problems, analyze and draw conclusions based on scientific evidence. These findings are supported by previous research that states that PBL-based digital comics are effective in increasing students' engagement and understanding in science learning (Destia Erfani, 2025).

In addition, the use of PBL-based interactive physics e-comic also increases students' motivation and interest in learning (Juwita et al., 2024). The character of the story and illustrations in the e-comic help students understand the relationship between the concept of physics and the phenomena in the surrounding environment, so that learning becomes more contextual. This is important because low science literacy is often caused by learning that focuses too much on memorizing concepts without connecting them to real-life situations.

This research offers a special contribution by integrating interactive physics e-comic and PBL models in an effort to improve students' science literacy, especially in fluid materials that are still relatively limited developed in previous research. Unlike previous research that generally only focused on the use of digital media or the application of PBL models separately, this study shows that the integration of PBL-based interactive physics e-comic is able to provide a more meaningful learning experience in improving students' science literacy.

### 5.2. *Implication*

The results of this study provide important implications in physics learning, especially in efforts to improve students' science literacy through the use of interactive physics e-comic based on Problem Based Learning (PBL). The findings of the study show that the integration of interactive digital media with PBL stages is able to create more contextual, interesting, and student-centered learning. Through the presentation of visual illustrations, real problems, and problem-solving activities, students not only gain a theoretical understanding of fluid concepts, but are also able to develop scientific thinking skills, analyze phenomena, and apply science concepts in daily life.

From a pedagogical perspective, this study emphasizes the importance of shifting learning from teacher-centered learning to student-centered learning that emphasizes students' active involvement in the learning process. The use of PBL-based interactive e-comics provides a more meaningful learning experience because students are encouraged to observe, identify problems, discuss solutions, and draw conclusions based on scientific evidence. These conditions support the development of 21st century skills, especially critical thinking skills, problem solving, communication, and science literacy.

In addition, this research also contributes to the development of innovative and adaptive physics learning media for the development of educational technology. The use of interactive e-comics can be an effective alternative learning medium, especially in fluid materials that are often considered abstract and difficult to understand by students. Visualization of concepts through illustrations and contextual stories helps students understand the relationship between physics concepts and phenomena in the surrounding environment so that learning becomes easier to understand and less monotonous.

Another implication can be seen in the flexibility of media use that can be applied in various learning conditions, both face-to-face and digital-based learning. This makes PBL-based interactive physics e-comic one of the relevant learning solutions to be used in schools with limited teaching media. Thus, the use of PBL-based interactive physics e-comic can be an effective learning strategy in supporting the improvement of the quality of physics learning and the development of students' science literacy.

### 5.3. *Limitation*

Although it has various advantages, interactive physics e-comic based on PBL to improve science literacy also has several weaknesses. One of them is the dependence on internet access which can limit its use in environments with low connectivity (Matuk et al., 2021). In addition, the process of developing interactive physics e-comics based on PBL takes a relatively long time, especially in designing relevant contextual problems and developing problem-solving flows that are able to encourage active student involvement. The products produced in this study are also still limited to one learning topic, namely fluids, so the scope of development still needs to be expanded.

## 6. **Conclusion**

Based on the findings, the development of interactive physics e-comic based on problem-based learning effective for improve students' science literacy, especially in fluid materials. This is shown by the increase in students' science literacy by comparing the results of the pretest and posttest of the N-Gain calculation to get a score of 0.76 with high criteria. In addition, the media developed is not only considered attractive by students and teacher, but also considered very feasible by media experts. Thus, this interactive physics e-comic has the potential to be an effective alternative physics learning media, especially in increasing students' science literacy in abstract materials such as fluids.

There are several recommendations that can be given for further development. First, interactive physics e-comics can be developed to include other physics materials so that their application is wider in learning. Second, it is necessary to integrate with e-learning platforms so that access to media is easier, structured, and does not depend on one particular application, one of which is Canva. In addition, further development can expand the variety of contextual problems presented, so as to be able to train students' abilities to analyze, evaluate, and solve problems scientifically as part of science literacy.

### Authors Contribution

**Ummu A'fifah:** Conceptualization, methodology, data curation, formal analysis, writing the original draft, review and editing. **Sri Latifah:** Conceptualization, methodology, review, editing, and supervision. **Sodikin:** Methodology, review, editing, and supervision. All authors have read and approved the final version of the manuscript.

### Ethical statement

This research has received ethical approval from the Research Ethics Committee of UIN Raden Intan Lampung, under approval number B-2896/Un.16/DT/PP.009.7/2026. All research procedures involving students are carried out in accordance with educational research ethics standards and applicable research ethics principles. Student participation in this study is voluntary. All participants were given explanations about the research objectives, implementation procedures, and benefits of the research. Approval was obtained from all research participants and teachers involved in the implementation of the research.

### Declaration of AI use

The authors used ChatGPT (OpenAI) to improve sentence clarity and readability in the original Indonesian draft. Gemini was used to translate the revised text into English. Finally, Grammarly was used to polish the English language (grammar, spelling, punctuation, and style). All AI-assisted outputs were reviewed and edited by the authors, who remain fully responsible for the accuracy, originality, and integrity of the final manuscript.

### Conflict of Interest

The authors declare that there is no conflict of interest, either financial or non-financial, that could be perceived as influencing the work reported in this manuscript. All authors have reviewed and approved this statement.

### Supplementary Materials and Data Availability

No public repository is currently available for the dataset. However, the instruments and key data summaries used in this study can be obtained from the corresponding author upon reasonable request. Any data shared will be anonymized and provided in accordance with the ethical approval and institutional regulations.

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## Appendix A. Research Instruments

**Table 19.** *Science Literacy Question Instruments*

No.	Indicators	Question Indicators	Question	Answer Key
1.	Explain the phenomenon scientifically (C2)	Explain the relationship between the depth of the object and the magnitude of hydrostatic pressure	Hydrostatic pressure experienced by an object will be greater when? A. The depth is getting deeper B. The surface area of the object is getting smaller C. The style is getting bigger D. The density of the object is getting smaller E. The depth is getting shallow	A
2.	(C3)	Explain the relationship between flow speed and fluid pressure	Water flows through a horizontal pipe whose cross-section narrows in one of the sections. When water passes through a narrow section of the pipe, it is seen that the speed of the water flow increases, while the pressure of the fluid decreases. This phenomenon occurs because? A. The density of water increases in narrow pipes B. The kinetic energy of the fluid is converted into potential energy C. The velocity of the fluid increases so that the pressure of the fluid decreases D. The force of gravity acts greater on narrow pipes	C

No.	Indicators	Question Indicators	Question	Answer Key
			E. Water discharge becomes smaller at narrowed cross-sections	
3.	(C3)	Explaining scientific phenomena through density calculations	A metal block with a mass of 2 kg has a volume of 0.00025 m <sup>3</sup> . What is the density of the metal? A. 4.000 kg/m <sup>3</sup> B. 6.000 kg/m <sup>3</sup> C. 8.000 kg/m <sup>3</sup> D. 10.000 kg/m <sup>3</sup> E. 12.000 kg/m <sup>3</sup>	C
4.	(C3)	Explain the phenomenon of change in flow velocity	In a city park, a water hose that was originally large in diameter was narrowed at the end to allow the water to spray further. The initial cross-sectional area of the interval is 0,03 m <sup>2</sup> with a water speed of 2 m/s. After the end of the hose is narrowed to 0,01 m <sup>2</sup> , the water velocity becomes? A. 2 m/s B. 3 m/s C. 4 m/s D. 6 m/s E. 8 m/s	D
5.	Evaluate and design scientific investigations (C4)	Evaluating the design of hydrostatic pressure experiments	Rafi wanted to investigate the relationship between fluid depth and hydrostatic pressure using a plastic bottle filled with water. He punched holes in the bottle at several different heights, then observes the water jets coming out of each hole. Which is the most appropriate research step to ensure that the results of the experiment are in accordance with the purpose of the investigation? A. Using bottles with different shapes for each hole B. Observing the color of the water coming out of each hole C. Keeping the fluid type the same and only changing the depth of the hole D. Resize the hole so that the water beam is clearly visible E. Changing fluids with different density on each experiment	C
6.	(C4)	Designing scientific research of dynamic fluids	A group of students wanted to investigate the effect of the width of a pipe cross-section on the flow speed of the fluid. They designed the experiment using pipes of several different diameters and flowing water at a fixed discharge. For such an investigation to be scientifically valid, the most appropriate course of action is? A. Changes the type of fluid whenever the diameter of the pipe changes B. Measuring flow velocity without regard to discharge C. Using pipes of different lengths D. Keeps the flow discharge constant and only changes the diameter of the pipe	D

No.	Indicators	Question Indicators	Question	Answer Key
			E. Observing the color of the water flowing in the pipe	
7.	(C5)	Evaluating conclusions based on theory	Alya conducted an experiment on the event of floating and sinking objects in water. Based on his observations, he concluded that all objects that have a large volume will inevitably float in the water. The proper evaluation of these conclusions is? A. That's right, because large volumes always produce a large buoyancy force B. Wrong, because what determines the floating or sinking event is the density of the object rather than the density of water, not just by its volume C. That's right, because a large object must have a small density D. False, because the volume does not affect the buoyancy at all E. Undefined	B
8.	(C5)	Evaluate statements about discharges based on the principle of continuity	In narrowed irrigation canals, the speed of water doubles. One farmer said that the water discharge also doubled. Based on the principle of continuity, the statement is? A. That's right, because the speed increases B. False, because the discharge remains throughout the flow C. That's right, because the area affects the discharge D. Wrong, because the pressure is increasing E. Cannot be analyzed	B
9.	Interpreting data and evidence scientifically (C4)	Determining the similarity of fluid masses	An object with a mass of 5 kg has a volume of 0.004 m <sup>3</sup> . If the object is put in water ( $\rho$ water = 100 kg/m <sup>3</sup> ), then the state of the object is? A. Floating B. Hovering C. Drowning D. Yawn E. Undefined	C
10.		Analyze the state of the object based on density comparison	Water flows in pipes with a cross-sectional area of 0.04 m <sup>2</sup> and a speed of 3 m/s. The pipe narrows to 0.01 m <sup>2</sup> . The speed of water in a narrow section is? A. 3 m/s B. 6 m/s C. 9 m/s D. 12 m/s E. 15 m/s	D

## Appendix B. Instruments Validation

The research validation instrument was used to assess the feasibility and attractiveness of developing an interactive physics e-comic based on problem-based learning. There are three types of validation: material experts, media experts, and experts in learning and test instruments. The validation stage was carried out

by two lecturers who are experts in materials, two lecturers in media, and two lecturers who are experts in learning instruments and tests.

The validation of science literacy questions is assessed based on three main aspects, namely: (A) Content, (B) Construction, and (C) Language. The assessment was carried out by setting a score of 1-4, namely: 1 (not feasible), 2 (less feasible), 3 (feasible), and 4 (highly feasible). The item-by-item scoring results of the expert validation for the science literacy test instruments are detailed in Table 20. Based on these scores, the overall eligibility percentages and criteria for each assessment aspect are summarized in Table 21.

**Table 20.** *Validation Results of Science Literacy Test Instruments*

No.	Assessment aspect	Question Number	Validator	
			V1	V2
1	Content	1	4	4
		2	4	4
		3	4	4
		4	4	4
		5	4	4
		6	4	4
		7	4	4
		8	4	4
2	Construction	9	4	3
		10	4	3
		11	4	3
3	Language	12	4	4
		13	3	4
		14	3	4
		15	2	4