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**Research Article**

# Problem-Based Learning Approach with Supported Interactive Multimedia in Physics Course: Its Effects on Critical Thinking Disposition

Gunawan GUNAWAN[1], Ahmad HARJONO[2], Lovy HERAYANTI[3] and Sadam HUSEIN[4]

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**Abstract**
In this research, interactive multimedia on thermodynamic concepts was developed and tested. The purpose of this research was to assess the effectiveness of interactive multimedia through a problem-based learning approach to students' critical thinking disposition. The research development had three stages: preliminary study, development, and field testing. The field testing was a quasi-experiment with a pretest and posttest control group design. The research subjects consisted of four lecturers as expert validators, two teachers and two groups of 65 students in a high school in Mataram city, Indonesia. Data were gathered by using questionnaires, observation, interviews, and written test. The results of the Normalized-gain test were 53.1 for the experiment group and 52.2 for the control group. This shows that there were differences in the increase of students' critical thinking dispositions between the control group and the experiment group. Therefore, it can be concluded that the application of interactive multimedia could improve students' critical thinking dispositions.
**Keywords:**
Interactive multimedia, thermodynamics, problem-based learning, critical thinking disposition.

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[1] Dr., Senior Lecturer, Department of Physics Education, Faculty of Teacher Training and Education, Universitas Mataram, Indonesia. It is gunawan@unram.ac.id Orcid no: 0000-0001-8546-0150.
[2] Dr., Senior Lecturer, Department of Physics Education, Faculty of Teacher Training and Education, Universitas Mataram, Indonesia. It is harjonofkip@unram.ac.id. Orcid no: 0000-0002-0632-7034.
[3] Dr., Senior Lecturer, Department of Physics Education, Faculty of Mathematics and Science Education, IKIP Mataram, Indonesia. It is lovyherayanti@ikipmataram.ac.id. Orcid no: 0000-0002-0565-2732.
[4] M.Pd., Research Assistant, Master of Science Education, Universitas Mataram, Indonesia. It is sadamhusein7991@gmail.com. Orcid no: 0000-0003-4415-4813.

## Introduction

One of the purposes of learning physics is to understand the development of science and technology that progress rapidly. This demands good quality in the physics learning process because a good learning process helps students deal with technological developments. According to Abubakar (2012), learning physics played an important role in the development of technology. The development of information and communication technology could be observed in its application in the learning process, especially in physics learning.

Thermodynamics is a branch of physics that studies the relationship between energy and work of a system. According to Hakim et al. (2017), thermodynamics has a diverse concept and some of them are very abstract, such as the concept of heat and entropy. Christensen et al. (2009) stated that most students had difficulties in understanding the entropy concepts (the second law of thermodynamics). This is causing difficulties in the learning process. According to Gunawan (2015), the implementation of computer technology in learning physics could help teachers overcome difficulties in visualizing abstract concepts. Furthermore, Pratidhina & Sumardi (2019) added that computer-based learning effectively increased student achievement.

Interactive multimedia is an example of the use of computer in learning processes. According to Gunawan & Liliasari (2012), multimedia is a system that supports communication of teachers with students during the learning process through text, audio, image, animation, video, and graphic. The application of interactive multimedia combined with the problem-based learning approach could help students in developing several thinking abilities. According to Hosnan (2014), problem-based learning helps students build critical thinking and problem-solving skills while developing students' ability to build their own knowledge actively.

The result in line with Kim et al. (2018), which stated that computer-based scaffolding is significantly impacted cognitive outcomes in problem-based learning in STEM education. Interactive multimedia has the ability to explain complex and dynamic concepts more clearly, facilitate to remember content easily, and improve understanding of topic content through student perspectives and ultimately make students more interested in learning (Chachil et al., 2014; Khan & M. Masood, 2015; Hwang et al., 2012). The development of students' thinking skills can be supported by the use of interactive multimedia in learning. Nowadays, multimedia are widely used in learning. Zumbach et al. (2004) and Hoffman & Richie (1997) successfully applied multimedia in supporting problem-based learning and resulted on increase in students' cognitive and motivation. In conclusion, theoretically, a combination of interactive multimedia with a problem-based learning approach supports each other in developing students' thinking abilities, one of which is the ability to think critically.

Most researchers also agree that in addition to skills or abilities, critical thinking also involves dispositions. According to Aprianti et al. (2014), one of the essential thinking abilities in physics is critical thinking dispositions. Critical thinking disposition is a person's tendency to behave in critical thinking. Halpern (1998) stated that by developing critical thinking dispositions, students can succeed in school and throughout their lives. Walker (2003) stated that to develop critical thinking, one must possess and use specific critical thinking disposition characteristics. His statement was supported by Facione et al. (1995), which revealed that someone who thinks critically uses seven dispositions to produce a decision. The aforementioned dispositions are systematicity, analyticity, open-mindedness, inquisitiveness, truth-seeking, self-confidence, and maturity.

Several studies on the application of multimedia had been conducted and produced positive responses toward conceptual mastery and critical thinking dispositions. Husein et al. (2019) suggested that the use of interactive multimedia had a positive effect on the conceptual understanding of thermodynamics. Along with that, Wahyuni et al. (2019) added that there was an increase in creativity by applying interactive multimedia rather than conventional learning. Gunawan & Liliasari (2012) also found that the use of a virtual lab of physics could improve critical thinking dispositions.

The number of benefits provided by the application of interactive multimedia and problem based learning approaches were the basis of the importance of this research. Interactive multimedia and problem-based learning (PBL) were both significant trends in contemporary educational practice but they have not been widely applied together (Albion & Gibson, 2000). Some studies (Hoffmann & Ritchie, 1997; Neo & Neo, 2001; Albion & Gibson, 2000) examined the effect of combining problem-based learning and multimedia, but most of them focused on the problem-solving skill or abilities, instead of students' critical thinking disposition. Therefore, more research is needed to understand the relationship between the application of interactive multimedia through a problem-based learning approach and students' critical thinking dispositions.

**Problem of Study**

Based on the description above, it was necessary to conduct research that aims to examine (1) the feasibility of interactive multimedia through a problem-based learning approach, (2) the practicality of interactive multimedia through a problem-based learning approach, and (3) the effectiveness of interactive multimedia through a problem-based learning approach on students' critical thinking dispositions.

## Method

### Research Approach

This was a research and development (R & D) based on steps proposed by Gall et al. (2003): preliminary study, development, and field testing. The field testing was carried out using the experimental method. This method used to determine product effectiveness. The effectiveness is related to an increase in critical thinking skills. Experiment design used quasi-experimental with control group pretest post-test design (Campbell & Stanley, 2015). The experimental group was taught with the help of interactive multimedia, while the control group uses basic media trough static pictures and video with no interactivity (only demonstration). The direct instruction approach was employed in both control and experimental groups as the instruction method.

### Participants

The validator team consists of experts and practitioners. The expert was a group master of sciences teaching lecturers in the Mataram University environment and practitioners from physics teachers. The limited trial subjects and effectiveness were high school students in the Mataram city, Indonesia. Limited trials were conducted on ten students (respondents) class XI in one of the high schools in the Mataram city. Afterwards, the effectiveness test was carried out in two classes in the same school. Participants of the research were 65 students, where 30 students were assigned in the experimental group and 35 students in the control group.

### Data Collection

This is a Research and Development study that requires many types of data (quantitative and qualitative). The assessment for effectiveness of the product required quantitative data from the critical thinking skills disposition test. Moreover, to the purposes of perfecting and validating multimedia, the qualitative data were collected through users' responses in the questionnaires and observation, documentation, and interviews with users during and after the classroom implementation.

Questionnaires were used to collect validation data from experts and practitioners as well as student responses to the use of problem-based learning interactive multimedia approaches for critical thinking dispositions. The critical thinking disposition test consists of ten descriptive questions on the thermodynamics topic. The test included disposition indicators of critical thinking according to Facione (2011) which are truth-seeking, open-mindedness, analyticity, systematicity, and inquisitiveness.

### Data Analysis

The effectiveness of interactive multimedia through a problem-based learning approach on students' critical thinking dispositions was determined based on normalized average gain scores. *N-gain* was obtained using the equation by Meltzer (2005):

$$N_{gain} = \frac{S_{\text{posttest}} - S_{\text{pretest}}}{S_{\text{maksimum}} - S_{\text{pretest}}} \times 100\%$$

Where N-gain is a normalized gain, $S_{max}$ is the maximum score (ideal) from the initial test and the final test, $S_{post}$ is the final test score, while $S_{pre}$ is the initial test score. The *N-Gain* scores can be classified as follows: (1) if g> 70, then the *N-Gain* is in the high category, (2) if 30 ≤ g ≤ 70, then the *N-Gain* is in the medium category, and (3) if g <30, then the *N-Gain* is in the low category. The independent sample test calculation was calculated using the SPSS 21 program for Windows, aimed to differentiate two groups of samples that do not influence each other.

Validation criteria were based on the average validation scores of all validators that were obtained and then transformed into intervals assessment categories by equations.

$$\text{Interval distance (i)} = \frac{\text{Max Score - Min Score}}{\text{number of criteria}}$$

(Widoyoko, 2012)

Based on the interval, the validity categories could be determined as in the following Table 1.

**Table 1.**
*Validation Categories*

| Percentage | Categories |
|---|---|
| 85%- 100% | Excellent |
| 69% - 84% | Very Good |
| 53% - 68% | Good |
| 37% - 52% | Fair |
| 20% - 36% | Poor |

**Process**

The interactive learning media was constructed by using the Adobe Flash CS3 software. The interactive learning media was divided into several sections: the opening section, main section, material section, evaluation section, and other information. The main sections of interactive learning media are shown in the following Figure 1.


The main menu consists of "competency", "material", "evaluation", "literature", "guidance", and "profile" of the media. Students could use this media interactively by selecting the corresponding menu.

The material page contains various kinds of information about thermodynamics. The concepts in thermodynamics such as the concept of heat, heat transfer, Carnot's law, and others. Students could learn thermodynamic in the form of simulations, texts, and videos.

The evaluation page presented several interactive questions related to thermodynamic material. The evaluation section has several multiple-choice questions with five-choices. Each question is adjusted to the competence related to thermodynamic material.

**Figure 1.**
*Example of Interactive Multimedia Displays and Related Information*

## Results

### Media Validation

Problem-based learning on thermodynamic concepts with interactive multimedia that developed to improve students' critical thinking dispositions was adapted from Facione (2011) and Gunawan (2015). The prototype of interactive multimedia was developed and then tested to assess its feasibility as a learning media by experts' assessment questionnaire. The responses were analyzed and the result can be seen in Table 2.

**Table 2.**
*Results of Expert Validation and Interactive Multimedia Material*

| No. | Aspect | Validator Scores | | | | Averages | Normalized Score |
|---|---|---|---|---|---|---|---|
| | | $V_1$ | $V_2$ | $V_3$ | $V_4$ | | |
| 1 | Contents | 41 | 40 | 42 | 42 | 41.25 | 91.67 |
| 2 | Language | 16 | 16 | 15 | 17 | 16 | 80.00 |
| 3 | Illustrations | 9 | 8 | 7 | 7 | 7.75 | 77.50 |
| 4 | Tools | 8 | 8 | 7 | 7 | 7.5 | 75.00 |
| 5 | Display | 9 | 8 | 8 | 8 | 8.25 | 55.00 |
| 6 | Interactivity | 15 | 16 | 15 | 15 | 15.25 | 76.25 |
| 7 | Audio | 15 | 15 | 15 | 16 | 15.25 | 76.25 |

| No. | Aspect | Validator Scores | | | | Averages | Normalized Score |
|---|---|---|---|---|---|---|---|
| | | $V_1$ | $V_2$ | $V_3$ | $V_4$ | | |
| Score averages | | 78.73 | 76.75 | 73.10 | 75.24 | | 75.95 |
| Categories | | Very Good | Very Good | Very Good | Very Good | | Very Good |

The result showed that the content aspect has the highest average score from experts. The total average score from experts was 75.95 (very good). Based on the result, it can be inferred that the developed interactive multimedia is suitable to use.

Further validation stage was done by practitioners: two high school physics teachers in Mataram, Indonesia. The average percentage of the practitioners' assessment is 75.95%. From the result, it can be seen that the developed interactive multimedia were feasible to use and minor improvements needed to enhance its quality.

**Students' Responses**

The limited trial aims to determine students' responses to interactive multimedia that have previously been through revisions based on the results of expert validation. During the learning process, students were given interactive multimedia for learning thermodynamics. Researchers observed the students' attitude towards the developed product and notified the problems that arise in the use of interactive multimedia. In the end of the learning session, the students filled out questionnaires about the use of interactive multimedia. The results of the researchers' observations and the results of student responses during limited trial activities are presented in Table 3.

**Table 3.**

*Responses of Students to Interactive Multimedia*

| Statements | Scores | Percent | Criteria |
|---|---|---|---|
| Positive | 55 | 88% | Excellent |
| Negative | 33 | | |

Based on the results of student responses to interactive multimedia, the percentage was 88% with excellent criteria.

**Media Effectiveness**

Test for increasing critical thinking dispositions using interactive multimedia was done by giving essay questions for the experimental and the control groups. The results are presented in Table 4.

**Table 4.**
*Results for Each Indicator Critical Thinking Disposition (CTD)*

| No. | CTD Indicators | Experimental Group N=30 | Control Group N=35 |
|---|---|---|---|
| | | *N-Gain* | *N-Gain* |
| 1. | Truthseeking | 32.8 | 40.7 |
| 2. | Open-mindedness | 53.1 | 51.7 |
| 3. | Analyticity | 33.5 | 25.2 |
| 4. | Systematicity | 33.7 | 29.3 |
| 5. | Inquistiveness | 52.6 | 41.8 |

The results show an increase in critical thinking dispositions on the Open-mindedness indicator of the experimental group with an average *N-Gain* value of 53.1 included in the medium category while the mean control group *N-Gain* value is 51.1 which is in the medium category.

**Table 5.**
*Independent Samples Test*

| Levene's Test for Equality of Variances | | f | p |
|---|---|---|---|
| N_gain | Equal variances assumed | 5.132 | 0.027 |

The hypothesis was tested using independent sample t-test. Based on the results of the independent Sample t-test for the experimental and control group, the sig value is 0.027. For the decision-making criteria for two-sided decision if the value of sig <0.05, this indicates a difference in the increase in learning before and after using interactive physics multimedia between the control and experiment groups.

## Discussion and Conclusion

The development of interactive multimedia aimed to simplify the learning process and students became easier to understand physics concepts. Interactive multimedia could be used as the tool to support interactive learning. The developed interactive multimedia consists of texts, images, graphics, sounds, videos, animations, and simulations that were put together into one unit to make it easier for students to understand thermodynamic concepts.

It consists of several parts that are integrated into a single computer software. The initial part is the opening section that contains the media title. The main part has a list of menus to access the features within the interactive multimedia. The material section consists of a combination of information in the form of text, images, videos, animations and simulations related to thermodynamics.

Based on the validation results from the experts, it was found that the developed interactive multimedia can be categorized as "very well". The average expert score is 75.95% on a 100% scale. There are seven indicators that determine expert validity, content, language, illustrations, equipment, interactivity, and audio.

On the content indicator, interactive multimedia gets an average score of 91.67% from the four validators. It can be understood that interactive multimedia content is excellent in terms of its content. The media are presented with attractive color combinations, good media appearance, and completeness of materials that are in accordance with the field competencies. Language was also assessed as an indicator of expert validation. The language indicators get an average score of 80% with the category of very good. The language used was adjusted to the standard language rules. The use of language that is easy to understand and neatly arranged makes it easier for students to understand the material provided.

The illustration indicators get an average score of 77.5% in the very good category. The selection of images and videos for interactive multimedia has been adjusted to the needs of students to understand the concept of thermodynamics. Indicator of interactive multimedia tools gets a score of 75% in the very good category. The user interface components provided in the media, such as buttons, simulation controls, and answer choices in the evaluation are designed with a simple style but still attractive to users. Students can also easily use every component provided because it has been given instructions for use in the media.

Interactive multimedia display is rated in good category by expert validators. The average score obtained is 55%. The display indicator is an indicator with the lowest average score and is one of the revised materials before being tested. The revision given is the reduction of text in the display material and adjusting the background color and text color combination to increase its readability. Media interactivity was also resulted in the very good category. The validator gives an average score of 76.25% for the interactivity and audio indicators. This average score indicates that the interactive multimedia feedback feature on user (student) input is rated very good by the validator. Audio media with good quality. So that student activities with interactive multimedia can be maintained both in terms of visual and audio.

Abstract concepts can be visualized with the help of this multimedia. According to Gunawan et al. (2018), visualization has a positive effect on students' conceptual understanding. A good visualization can stimulate students' minds to understand the material more creatively. Adawiyah et al. (2019) stated that the addition of multimedia has been able to improve creative thinking skills. If the creativity of students increases, it will be easier for students to find their learning patterns that are suitable for maximum learning outcomes. Ramadhani et al. (2019) also added that the application of computer-based media that is integrated with the system is also proven to be able to increase student motivation. Right motivation and creativity will highly support students' development, especially the development of special abilities, such as problem-solving skills.

Interactive multimedia through a problem-based learning approach is a learning activity that involves students to try solving their problems with interactive multimedia. Argaw (2017) argued that problem-based learning is a good learning approach to improve learning achievement through group discussion and independent learning. Arends (2008) divided the stages of the problem-based learning approach into student orientation to the problem, organizational students, individual and group search guides, develop and present the work, analyze and evaluate the problem-solving process.

The multimedia was applied in these stages to support the problem-solving process. For example, to solve problems with thermodynamic material correctly, the information presented in the interactive multimedia provides a contextual example. Interactive media displays simple animations with appropriate usage instructions. In addition, the language presented is simple and does not give rise to double meanings so that students easily understand the material contained in interactive multimedia.

Interactive multimedia through a problem-based learning approach provides an essential role in the learning process. According to Isnaneny et al. (2016), PBL-based interactive multimedia can improve the thinking ability of teacher candidates. One of these abilities is critical thinking dispositions. Critical thinking dispositions consist of 5 indicators examined in this study, each of which has unique findings, and the description is as follows. Open-mindedness means providing a new space in thinking because there is a simulation that acts as the content of discussion assisted by student worksheets. This is in accordance with the *N-gain* results on the Open-mindedness indicator having the highest increase.

A considerable increase in the truth-seeking indicator presents a statement about the balance of rigid bodies. According to Facione et al. (1995), truth-seeking is a skill to tend to seek the best knowledge in specific contexts, dare to ask questions, and be honest. In interactive multimedia, there is a simulation content in the form of a virtual lab that explains the thermal balance process. According to Hermansyah et al. (2019), the application of virtual labs can improve students' understanding of the concept of heat. Gunawan et al. (2018) added that the use of virtual labs could improve students' creativity because students' creativity is very influential in students' conceptual understanding.

The difference in improvement in these two indicators is easy to understand because there is an initial frame of mind that already exists for each student. The learning process shows a tendency of students to maintain their frame of mind until they get a rational explanation or picture that causes a strengthening of the validity of the mindset. The shift in paradigm is in appropriate direction if the existing framework is not right.

The lowest increase in both groups occurred in the analytic indicator. The results of the interviews indicate that students have difficulty explaining the P-V graph. Gunawan & Liliasari (2012) found that truth-seeking and analyticity are indicators that often get lower results. According to Meltzer (2005), most students have difficulty in understanding the dynamic processes associated with the P-V diagram. This shows that students' preparedness for possibilities that can occur still needs to be improved.

Hypothesis testing was carried out to test the difference in improvement in the two groups. The test uses analysis of variance from independent sample t-tests using SPSS 21 software for windows. The significance value obtained was 0.027 < 0.05. This shows that there are differences in the increase in students' critical thinking dispositions in both groups, which is the implication of the use of interactive multimedia in the learning process. Mashami & Gunawan (2018) stated that animation media has a positive impact on students' critical thinking abilities, both in male and female students.

In the classroom implementation, interactive learning multimedia makes it easy for teachers to help students to observe problems through a video display. As Ibrahim (2000) stated, giving problems at the beginning of learning helps students develop thinking abilities, problem-solving, intellectual skills, and become independent learners. This problem-based learning is focused on the development of student learning, not to help teachers collect information that will be given to students during the learning process.

Interactive multimedia through a problem-based learning approach to physics teaching has advantages such as emphasizing the activity of students in learning, which is indicated by students' curiosity in learning. This is reinforced by Persson et al. (2010), that adding interactive multimedia through a problem-based learning approach made students more motivated and stimulated in learning process. Interactive multimedia was indeed very suitable to be applied in developing a range of high order thinking skills (Dasilva et al., 2019) and science process skills (Gunawan et al., 2019), this factor greatly influences the development of students' problem-solving skills.

Computer-based media is also able to prevent students from misunderstanding the concept (Yumuşak et al., 2015). In the process of developing high-level abilities, there is the possibility of miss thinking disposition, and the application of interactive multimedia can prevent that from happening. This shows that learning with interactive multimedia was effective in improving students' disposition of thinking and maintain its development in the right direction.

Based on the result of the research, it can be concluded that (1) the thermodynamic interactive multimedia that develop based on problem-based learning can be used as a supplementary tool in learning process; (2) The highest improvement from critical thinking disposition was on the open-mindedness indicator and the lowest on systematicity indicator; (3) the developed thermodynamic interactive multimedia can improve the disposition of critical thinking of the students.

## Recommendations

The authors provide suggestions for further research that can apply interactive learning media to examine other thinking skills. Interactive multimedia must be adapted to the skills that will be developed. The potential of interactive multimedia on students' skills development has been proven theoretically and empirically, but more data are still needed for media specifications that are relevant to student learning needs. Finally, the authors also suggest further research in order to develop interactive media combined with other learning methods, to obtain more in-depth and broader data.

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## Biodata of the Authors

**Dr. Gunawan, M.Pd.** was born at Sumbawa, on May 1st, 1981. The author is a Senior Lecturer in Physics Education, the Faculty of Teacher Training and Education, Universitas Mataram. He completed his doctoral program in a science education study program at Universitas Pendidikan Indonesia in January 2011. Currently, he is the Director of the research center for physics and technology education, Universitas Mataram. His research focus in recent years has been in the development of virtual laboratories, interactive multimedia, and learning management systems.

**Affiliation:** Dr., Senior Lecturer at Department of Physics Education, Faculty of Teacher Training and Education, Universitas Mataram, Indonesia.

**E-mail:** gunawan@unram.ac.id

**Phone:** +6281246673311

**Dr. Ahmad Harjono, M.Pd.** is a Senior Lecturer in Physics Education, the Faculty of Teacher Training and Education, Universitas Mataram. He completed his doctoral program in an educational technology at Malang State University. Currently, he is the Chair of the Physics Education Study Program, University of Mataram. His research focus is on developing learning media, learning styles, advance organizers, and thinking skills.

**Affiliation:** Dr., Senior Lecturer at Department of Physics Education, Faculty of Teacher Training and Education, Universitas Mataram, Indonesia.

**E-mail:** harjonofkip@unram.ac.id **Phone:** +6281357036317

**Dr. Lovy Herayanti, M.Pd.** is a Lecturer in Physics Education, the Faculty of Mathematics and Science Education, IKIP Mataram, Indonesia. She completed her doctoral program in a science education study program at Surabaya State University in February 2018. Currently, she is actively researching several issues related to information technology applications in science learning. **Affiliation:** Dr., Senior Lecturer at Department of Physics Education, Faculty of Mathematics and Science Education, IKIP Mataram, Indonesia. **E-mail:** lovyherayanti@ikipmataram.ac.id **Phone:** +6281910607354

**Sadam Husein, M.Pd.** was born in Plampang (Sumbawa) on September 7, 1991. The author continued his undergraduate studies in the physics education study program at IKIP Mataram. Then proceed to the Master program of science education at Mataram University and graduate in 2019.
**Affiliation:** M.Pd., Master of Science Education, Universitas Mataram, Indonesia. **E-mail:** sadamhusein7991@gmail.com **Phone:** +6285338622221

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