



LEARNING DESIGN FOR LIGHT WAVE ORIENTED TO THE MULTIPLE-REPRESENTATIONS OF HIGH SCHOOL STUDENTS IN EAST ACEH

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ABSTRACT

Several studies have shown a deficiency in multiple-representation skills among high school students in East Aceh, where the learning process has not fully accommodated the development of these skills. This research aims to develop a learning design focused on enhancing students' multiple-representation abilities in the subject of light waves. The methods used include surveys and design research, with data collection utilizing validation sheets, pretests, posttests, and interviews. The validation results indicate a very valid category for question instruments, worksheets, and media. An initial survey of 30 high school students in East Aceh revealed an average initial multiple-representation ability of 28.4%. After limited implementation of the learning design, students' multiple-representation ability increased to an average of 61.8%. Thus, this learning design has proven effective in enhancing students' multiple-representation skills. Future research could evaluate its application in other subject materials.

DESAIN PEMBELAJARAN MATERI GELOMBANG CAHAYA BERORIENTASI PADA KEMAMPUAN MULTIREPRESENTASI SISWA SMA DI ACEH TIMUR

ABSTRAK

Beberapa penelitian telah menunjukkan adanya kekurangan dalam kemampuan multirepresentasi pada siswa SMA di kawasan timur Aceh, di mana proses pembelajaran belum sepenuhnya mengakomodasi pengasahan kemampuan ini. Penelitian ini bertujuan mengembangkan desain pembelajaran yang berfokus pada pengembangan kemampuan multirepresentasi siswa dalam materi gelombang cahaya. Metode yang digunakan meliputi survei dan penelitian desain, dengan pengumpulan data menggunakan lembar validasi, pretest, posttest, dan wawancara. Hasil validasi menunjukkan kategori sangat valid untuk instrumen soal, lembar kerja, dan media. Survei awal pada 30 siswa SMA di Aceh Timur menghasilkan rata-rata kemampuan multirepresentasi awal 28,4%. Setelah implementasi terbatas desain pembelajaran, kemampuan multirepresentasi siswa meningkat menjadi rata-rata 61,8%. Dengan demikian, desain pembelajaran ini terbukti efektif untuk meningkatkan kemampuan multirepresentasi siswa. Penelitian selanjutnya dapat mengevaluasi aplikasinya di berbagai materi pelajaran lainnya.

Kata Kunci:

Desain pembelajaran

Gelombang cahaya

Multirepresentasi

1. INTRODUCTION

Representation can be interpreted as modelling concrete things into abstract concepts or symbols. As an abstract subject, physics is fundamentally represented in mathematical language, and physicists use mathematical modelling to predict the behaviour of natural systems [1]. Modelling and representations were placed together because representations are tools for modelling; they are what models are made of [2]. Bollen, et al say that mathematical or physical concepts or problems can be expressed in various ways. It can be a complete textual description of a situation, a symbolic expression, a graph, an image, a diagram, and so on, these different forms are called representations [3]. Multiple-representation refers to a person's ability to represent information in various forms or formats, including visual, verbal, or symbolic. Multiple-representations can be interpreted as a concept arrangement conveyed by written verbal sentences, symbols as mathematical forms, images and graphics in conveying data information [4]-[7]. Multiple-representational understanding is students' understanding of visual, verbal, and mathematical images and graphics [8].

Instructors and researchers in physics education research have argued that students can benefit from solving problems that require using multiple-representations simultaneously [9]. Problems in multiple-representations are certainly different from other problems. Of course, someone will find it more difficult to imagine the solution to a physics problem or understand logically a physical phenomenon with just one representation. For example, if someone can represent an idea in an image, diagram, text, or table, he has multiple-representation abilities. This ability is critical in various contexts, including learning and problem-solving. With multiple-representation capabilities, a person can understand information from multiple perspectives and thus can solve problems better [1]. Furthermore, multiple-representations can also help someone communicate their ideas more effectively.

Physics is a subject that is difficult for students to understand because it is a multidisciplinary subject. Someone who wants to understand physics must be skilled in using mathematics as a tool, be able to describe a phenomenon and explain logically how the phenomenon occurs. Therefore, more than one symbolic format in physics is often used to convey information and support knowledge construction [1]. Different understanding and representation abilities are needed for the concepts studied [2]. Students' inability to use different representations in understanding physics concepts seems to be a difficulty for students [10]. Finally, it forms the image that physics is difficult to understand. Learning with multiple-representations has been recognized as a potentially powerful way of facilitating understanding in science [7].

Light waves are a high school physics material requiring a lot of representation to explain the concept. The material of light waves is part of physical optics, which discusses the properties of light, such as reflection, refraction, diffraction, interference, dispersion, and polarization. Most students still have difficulty understanding the concept of light waves, which are not only explained in verbal representations but also must be explained in the form of physical representations such as pictures, diagrams, graphs, and mathematical representations [11].

The research results show that the ability of high school students in East Aceh to understand physics concepts is still low [12]. Based on research by Fitri, Munzir, and Duskri, the multiple-representation of high school students in one of the state schools in the East region of Aceh is less than 76% who have abilities in the medium-low interval [13]. Learning designs and learning strategies are needed that are oriented towards students' multiple-representations that can make it easier for students to understand physics

concepts, especially light waves [14], because there is an interaction effect of the learning model and cognitive style towards improving representation ability [15]. No previous research has developed learning designs, especially on the light wave, which is oriented towards multiple-representations.

Some existing research includes developing teaching modules on static fluids [7], linear motion [8], harmonic vibrations [14] and Newton's law of gravity [6]. This research aims to develop a learning design for light wave material oriented towards the multiple-representational abilities of high school students in East Aceh. No previous research has developed a learning design, especially on light wave material, oriented towards students' multi-representational abilities.

The aim of this research is to develop a learning design for light wave material oriented towards the multiple-representational abilities of high school students in East Aceh. The distinction of this research from previous studies lies in using light wave materials and multiple-representation. This novelty is hoped to have a positive impact on the students.

2. METHOD

The research methods used in this research are survey and development with design-based research/design research. One of the distinguishing features of design research is that principles and hypotheses about learning are embedded in the design of innovations. Designed innovations are often based on theoretical premises with the main theoretical constructs embodied in the designed artefacts [16]. This research focuses on creating learning designs oriented towards multiple-representation abilities. The learning design was implemented at SMA Negeri 1 Ranto Peureulak, East Aceh Regency, Aceh. This research consists of four stages: preliminary research (initial data collection) for need and context analysis, development or prototyping, formative evaluation, and reflection and documentation [17]. Details of the research stages can be seen in the flow diagram (Figure 1).

This research data is in the form of data from the validation of the multiple-representation instrument and validation of the developed student worksheet. Student worksheets are one of the suggestions for learning activities that can facilitate learning activities and help students understand the material being studied [18], [19]. Validation was carried out by two experts: one lecturer in the Physics Education study program from Bengkulu University and 1 lecturer in Science Education from Gorontalo State University. The validation results were analyzed using the coefficient V formula [20].

$$V = \sum s / [n(c - 1)] \tag{1}$$

With:

$$s = r - lo$$

lo = The lowest validity assessment number.

c = The highest validity assessment number.

r = A value given by the researcher.

This table of value interpretations is from Aiken's V [20].

Table 1. Interpretation of Aiken's V

Coefficient Aiken's V	Criteria for Validity
$0,80 < V < 1,00$	Very high
$0,60 < V < 0,80$	High
$0,40 < V < 0,60$	Moderate
$0,20 < V < 0,40$	Low

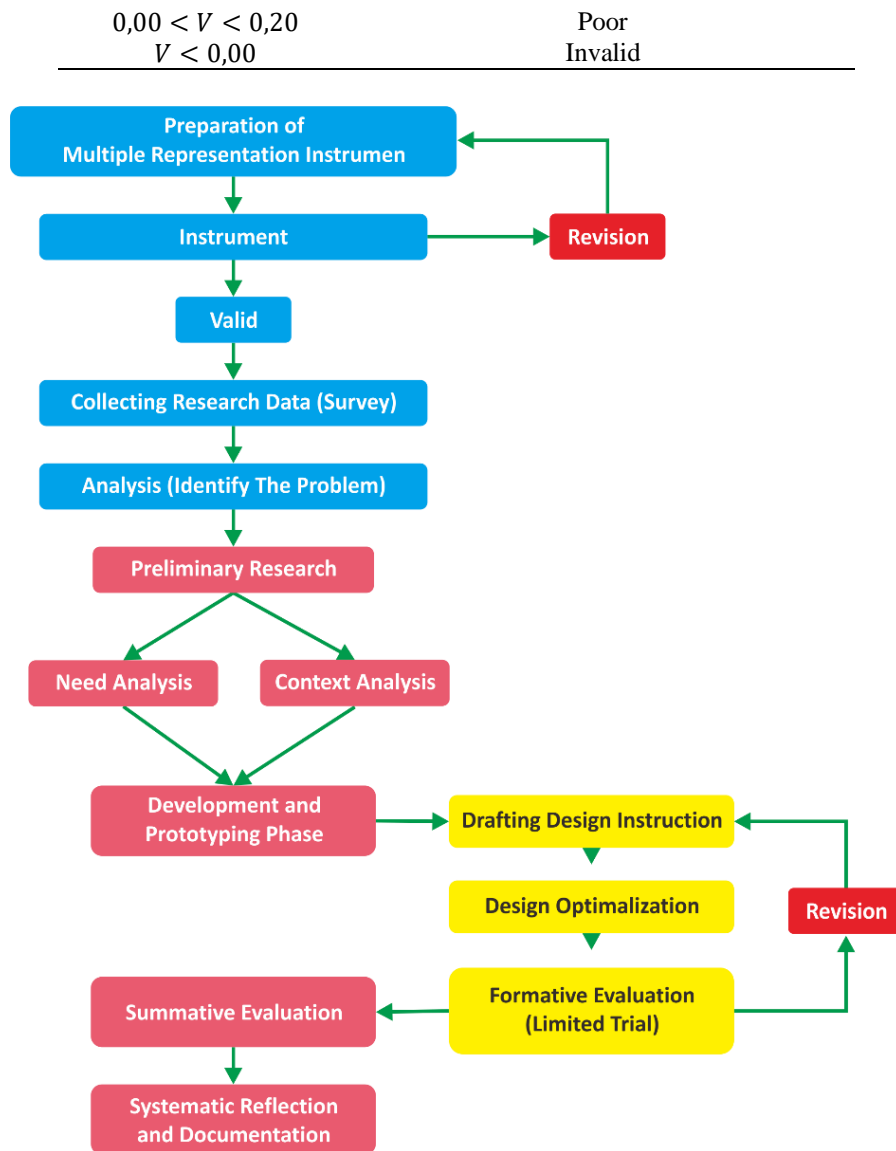


Figure 1. Flow Diagram of Research

Valid test instruments will be tested on a limited number of participants to measure students' multiple-representations. Data from the test was analyzed using descriptive statistics to describe the condition of students' multiple-representations. Student responses to physics learning and descriptions of students' conditions were elaborated through interviews with several students. Data analysis of students' multiple-representation abilities was carried out by calculating each indicator's percentage of multiple-representation ability scores using the following formula [21].

$$\% = \frac{\sum n}{\sum N} \times 100 \quad (2)$$

With:

- n = Total score by students
- N = Maximum total score
- % = Percentage

The results of the multiple-representation ability scores can be categorized as follows [21].

Table 2. Multiple-representation Category

Percentage (%)	Category
81-100	Very high
61-80	High
41-60	Moderate
21-40	Low
0-20	Poor

3. RESULTS AND DISCUSSION

The aim of this development research is to develop a learning design oriented towards students' multiple-representation abilities in light waves. The learning design developed is a series of learning instruments in Merdeka curriculum teaching modules complete with student worksheets and question instruments.

Before developing the product, the team collected initial data as a preliminary, which included compiling pretest and posttest instruments as multiple-representation questions and semi-structured interviews. The test instruments developed in this study are arranged in essay form. Initial data collection aims to obtain a reflection of initial multiple-representations before treatment is given. The instruments compiled were validated by experts, consisting of two lecturers from outside Samudra University who were lecturers in physics education study programs. As evidence of the assessment instruments' quality, researchers used validity. The validity refers to the measurement accuracy. It relies on how good measurement tools can measure the final result [22]. The validation results of the multiple-representation questions are presented in Table 3.

Table 3. Multiple-representation Validation Results

Indicator	Validation Result
Content	0,97
Construction	0,95
Language/Grammar	0,94
Average	0.95
Category	Very high

Table 3 shows that for each indicator of assessment of the content, construction and language of the questions developed, an average score of 0.95 was obtained, including in the very valid category. It means that the instrument created can measure multiple-representation abilities objectively and accurately. The instruments are made in essay form. The essay form was chosen because it can require students to express their understanding in their own words, reduce the opportunity for lucky guess answers, and show the level of students' understanding of the problems asked more accurately. Researchers conducted logical analysis when compiling this instrument, including content, construct, and language. Content analysis is intended as a study related to the scientific substance asked in the question as well as the level of ability appropriate to the question. Construction analysis is intended as a study generally related to question writing techniques. Language analysis is intended to study questions related to the good and correct use of Bahasa [23]. However, there were several improvements from validator 1 in the construction indicators in the form of several question item statements that had not been formulated clearly. They are in questions 1, 2, 5, 6, 7, 11, 15, 17, and 20. The question narrative was then corrected, as in the following example.

The results of the validation of the multiple-representation questions reached the instrument validity criteria and were suitable for testing. The instrument testing process for multiple-representation questions was conducted on 30 students of the 11th grade of

Ranto Peureulak 1 Senior High School, East Aceh, in August 2023. Before the learning process, students were given pretest questions to determine their initial abilities in solving multiple-representation questions. The results show that verbal representation is 28%, image representation is 27%, mathematical representation is 33%, graphic representation is 28%, and table representation is 26%. The average multiple-representation ability is 28.4% still in the low category.

Besides that, to support the data on the pretest results, the team interviewed a physics teacher and three 11th-grade students (randomly) who were given the pretest at the school. From the results of teacher interviews, information was obtained that teachers still use the speech/discourse method (teacher-centred), rarely do practicums or use technology in learning. Meanwhile, the results of interviews with students showed that it was easiest for students to understand physics with the teacher's explanation through verbal language, symbols, and pictures. Students have difficulty understanding graphs and tables because students are rarely accustomed to solving problems in this form of representation. Teachers still use ordinary questions through verbal representations and mathematical equations. Therefore, the need to develop learning designs oriented towards multiple-representational abilities is very necessary. The data from this interview is also used as material for needs analysis and context analysis at the learning tool development stage.

3.1 Need Analysis

A needs analysis looks into stakeholders' perceptions of the current situation and the features of a more desirable situation [24]. Needs analysis data was obtained from pretest results, which were elaborated on through interviews. Overall, students' initial multiple-representation abilities are still relatively low. Verbal representation is 26%, image representation is 27%, mathematical representation is 33%, graphic representation is 28%, and table representation is 26%. The results of the elaboration through interviews strengthen the pretest results. Based on an interview with one of the physics teachers, it is known that the teacher teaches using the speech/discourse method, meaning that learning is still teacher-centred. Students often have difficulty understanding the material, but the teacher does not find out the cause of the student's difficulties. Besides, teachers find it difficult to explain pictures and graphs so students can easily understand them. Lastly, teachers rarely use technology in learning. Meanwhile, on the student side, students have difficulty answering questions that contain formulas, pictures and graphs.

Based on this information, the team concluded that students need to be familiarized with multiple-representations, especially the representation of formulas, pictures and graphs. Formulas related to mathematics and the interaction of learning models and cognitive styles have a major influence on mathematical representation abilities [15] and the representation of pictures and graphs. Thus, to facilitate this, learning needs to be structured based on physical phenomena (simple experiments), translated into mathematical symbols and formulas, represented in table form, and represented in the form of pictures/graphs. The delivery of information in learning is student-centred with cooperative learning or open discussion.

3.2 Context Analysis

Context analysis aims to explore the problem environment and map out the scope for innovation [25]. Context analysis data was obtained from interviews with students, physics teachers, vice principals in curriculum fields, and observations of the school environment. This activity shows that the product user will be an 11th-grade physics teacher with a Bachelor's degree in Physics Education and more than five years of teaching experience.

The team assumes that teachers will easily understand and use our products. The teacher has good class control, as seen during our observations during the teacher's teaching hours.

However, the problem is the tools and teaching materials available for simple experiments. Physics teaching aids and materials are classified as lacking, so this is a note for the team when designing the product. An alternative solution is to use trial video media, which can be easily accessed for free. Using videos in physics learning effectively improves learning outcomes and encourages students to be active in learning [26], [27].

3.3 Prototyping

After the initial data is collected, we enter the product development stage. Based on the needs analysis and context analysis that has been carried out, the team created a teaching module prototype complete with student worksheets called the product. The product is made to be easy for teachers to use and improve students' multiple-representation abilities. The teaching module is also equipped with simple experimental stages. It includes an alternative experimental video link if the tools and materials for the experiment are not available so that students can still see physical phenomena in real life, not just in written form. At the end of each sub-material in the teaching module, evaluation questions are also included as validated post-test questions. The posttest questions consist of two aspects of multiple-representations: the ability to represent various forms of verbal representation, pictures, tables, graphs, diagrams and mathematical equations, as well as the ability to translate various forms of representation, tables to pictures, verbal to graphs, tables to graphs and mathematical equations to verbal.

Validation was also carried out on the Student Worksheets instrument, which contains the sub-materials of reflection, refraction, interference, diffraction and polarization of light. Validators come from the Physics Education study program from outside Samudra University. The following are the validation results of the Student Worksheet instrument for material and media studies, presented in Tables 2 and 3.





Figure 2. Modul Appearance as Part of the Product

Table 2. Student Worksheets Validation Result for Content

Indicator	Validation Result
Grammar	0,83
Suitability of worksheet and indicator	0,80
Content suitability	0,93
Average	0.85
Category	Very valid

Based on Table 2, the student worksheet validation results for the content studies for each indicator obtained an average score of 0.85, including the very valid category.

Table 3. Student Worksheets Validation Result for Media

Indicator	Validation result
Dimension	0,80
Cover design	0,80
Illustration	0,80
Content design	0,80
Practical step	0,85
Problem context	0,80
Physical concept	0,80
Language	0,80
Average	0.80
Category	Very valid

Based on Table 3, the student worksheet validation results for media studies for each indicator obtained an average score of 0.80, including the very valid category. The following is a display of the developed student worksheets. This student worksheet has received good validation because it was prepared based on the references of the main student worksheet. The indicators that are the main reference in developing student worksheets include format, language, and content [28].

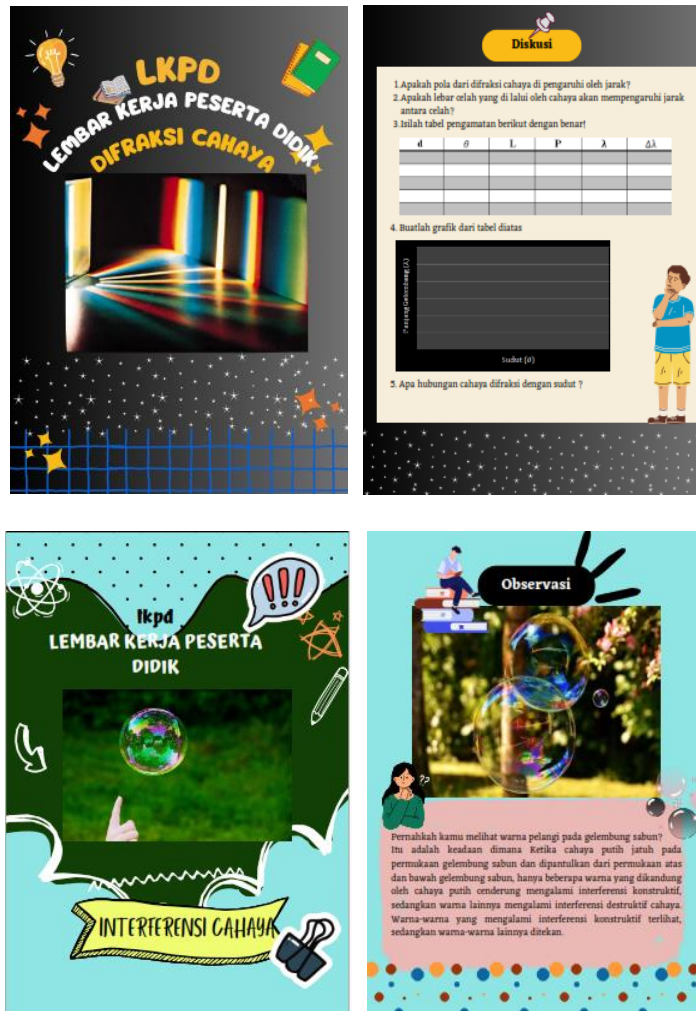


Figure 3. Student Worksheets Appearance

3.4 Formative Evaluation

During the formative evaluation phase, the team carried out experiments in the form of limited trials on 30 11th-grade students at Ranto Peureulak 1 Senior High School. Students were taken through purposive sampling adapted to learning at the school. Then, learning was carried out with products developed on light waves with interference and light diffraction as sub-materials. Learning was carried out in 2 meetings with students doing practicum using the student worksheets that had been developed. Students are directed to multiple-representation skills, verbal skills, pictures, tables, graphs, and mathematical equations through student worksheets. Students are accustomed to writing down experimental data in the form of pictures, tables and graphs. Students are trained in verbal representation and mathematical equations when analyzing experimental data.

After learning, students are given posttest questions to determine the increase in students' multiple-representation abilities. The posttest results showed an increase in students' multiple-representation abilities in each representation. The average score obtained was 61.8%, which was in the high category. The highest score in the pictorial representation was 87%, and the lowest was in the graphical representation, 35%. The data from the pretest and posttest results are presented in the following picture.

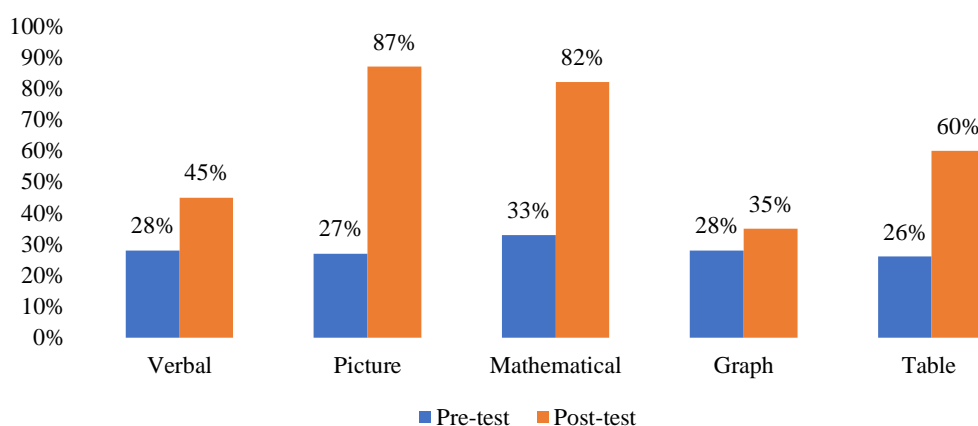


Figure 4. Pretest dan Post-Test Data Result

Based on the entire design research process. The product shows results following what the researchers targeted. Each stage is carried out by paying attention to many aspects so that validity testing and limited trials produce positive values. However, this formative evaluation stage is the first cycle, so further testing and development needs to be carried out to obtain consistency and practicality of the product being made. Ultimately, the summative evaluation stage will determine effectiveness and practicality before the product is widely used [24].

The science classroom should include opportunities for students to use science language, including the different representations typically employed by scientists as they communicate [29]. Students with multiple-representation abilities have implications for a good understanding of concepts [30]. Multiple-representations open up opportunities for students to understand content through representations that students know. So, a multiple-representation approach is very good for training students to master the studied concepts. This is because displaying various representations in the cultivation of a concept is predicted to be more helpful for students in understanding the concepts being studied because this is related to each student having specific abilities. More prominent than other abilities [31]. In the future, human learning will be increasingly (multiple) representational as we constantly invent new forms of representations whose appearance and interactive possibilities are partly due to technological development [32]. Future research could evaluate its application in other subject materials.

4. CONCLUSION

Physics is a lesson that explores natural phenomena. To understand it, we must translate the phenomenon into our language through mathematical symbols, pictures, graphs, tables and other forms. That is actually what is called multiple-representation. In other words, studying physics requires good multiple-representation skills. We need to explain and familiarize students with this at the secondary school level. In cases where students' multiple-representations are low, we must strive to improve learning to increase students' multiple-representations so that physics learning goals can be achieved. After a long process that ended with limited trials, it can be concluded that this product can be used to increase student representation. Through this product (teaching module and student worksheets on light waves), we strive to improve students' multiple-representation abilities to understand physics well in various representations. It can be seen that based on the results of the pretest and posttest, the ability of each student representation has increased with an average increase of 33.4%.

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