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Multirepresentation Ability Analysis of Wave Matter Using Physics Education Technology

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Abstract: Education is the primary capital of a nation's progress, because with education, the human resources that a nation possesses will become quality. Physics is a branch of natural science, specifically studying natural phenomena and events through several scientific and systematic methods. The research is aimed at developing a tool to evaluate the multirepresentation of wave matter using Physics Education Technology. The methods used in this research are quantitative methods and the research is carried out by providing filling issues that will analyze verbal multirepresentation capabilities, tables and graphs. The research will be carried out at Semarang University using samples of civil engineering students. Research procedures through preliminary stages by drawing up a research plan. Preparing and compiling wave learning modules using the simulation facilities of Physics Education Technology, then compiling evaluation tools that are subject-based with multi-representation verbal approaches, tables and graphs. Validation of learning modules and evaluation tools to determine whether it is worthy of use or not, validation is carried out by 2 experts. Validation of test instruments by experts on material aspects averaged 93%, on construction aspects 94% and on language aspects reached 92%, of which results show that the instruments have excellent validity. In the finite scale test, the highest multirepresentation ability is communicating from mathematics to verbal and its mathematical abilities, while the lowest is in the ability to picture to mathematics and physics.

Keywords: Multirepresentation; Physics education technology

Introduction

Education is the primary capital of a nation's progress, because with education, the human resources that a nation possesses will become quality. In line with the evolution of the world paradigm on the meaning of education, education is facing an increasing number of challenges. The differences in the educational process of decades ago, where the education system of the era now weighs up the competence of graduates who have the ability to communicate and think well.

Physics is a branch of natural science, specifically studying natural phenomena and events through several scientific and systematic methods. Scientific methods can be structured systematically ranging from observation activities, making hypotheses, experiments and data evaluation (Azizah et al., 2015). In the process of learning the science of physics requires methods that relate to understanding the basic concepts as well as in solving the problem of the physics itself. The most important things are the basic concepts for solving physical problems, the mastery of concepts and the problem-solving skills required by students. Besides, interaction in the learning process is also very needed in the delivery of material, the availability of learning media, the use of teaching materials in the proper

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evaluation process so that the learning objectives can be achieved accurately and efficiently.

Some matter of abstract physics such as matter of atomic physics, quantum physical, wave physics and statistics will be difficult to understand without using a learning approach that matches its characteristics. The multi-representation approach in the context of physics learning is a view of the repetition of concepts and equalization of physical concepts with various models of presentation such as graphs, diagrams, mathematical equations, symbols and assistance of information technology (Nikat et al., 2021). The replication of the physical concept is based on the selection of representation formats that correspond to the characteristics of matter such as the abstract physical concept and to visualize phenomena so as to streamline the learning process (Sari et al., 2021).

Based on this, the question that arises is how to find the best way to convey the material taught so that students can understand and remember the materials taught and the ability to solve problems in high physics, so that the ability of multirepresentation can arise from students. Very rapid technological developments can be used to help complete an abstract understanding of physics. PhET (Physics Education Technology) is a simulation of the sciences of physics, chemistry, biology of earth sciences and mathematics. This site provides free learning simulations to download in the interests of classroom learning or self-learning.

PhET is a learning software from the University of Colorado. Research on PhET virtual labs in which students are invited to provide the response that exists in the virtual lab, then computers will respond and provide feedback can improve students' cognitive capacity (Hamida et al., 2013). Features of a virtual laboratory are programs that contain laboratory tools that work just like a real tool. Students are asked to give the response which exists at the virtual laboratories, then the computer will reply and provide immediate feedback to the user in the form of an instruction program (Hamida et al., 2013). The web-based virtual lab display format can help students to conduct their internships independently. Virtual Laboratory is classified as 5 (Saputra, 2017), that is: classical simulation that contains the elements of a specific laboratory experiment and is available there (simulation); classic simulation which contains elements of certain laboratory experiments and can be accessed online (cyber laboratory); simulation that tries to present the lab experiment that is as compatible as possible with a real experiment (virtual lab); simulation of a laboratory that conducts experiments using virtual reality techniques (VR lab); and real experiment controlled via a network or the Internet (internet lab).

Physics practice is a compulsory thing to do, with technological advances of many applications that can be used to replace practicum in person. Some applications can use video tracker analysis, science edu and PhET. PhET is an interactive simulation of physical phenomena, based on research given free of charge (Zahara & Setiawaty, 2018).

Multirepresentation aims for students to get various representations of a material. The development research method used is the ADDIE design development method. This method was chosen because it is one of the basic development methods and is easy to implement (Prahastiwi & Zain, 2023). the results of research that has been carried out, then the effectiveness of students' learning outcomes and multirepresentation using the scientific reason-based module has increased (Anwar et al., 2018). the aplication of physics learning with multirepresentation based can improve the ability of representation of students (Muzdalifah et al., 2019). An extensive empirical study on two multi-turn response selection data sets indicates that our proposed model achieves a new state-of-the-art result (Mao et al., 2019). effectiveness includes critical thinking skills and student responses to the application of multi-representation-based physics modules (Mahardika & Wicaksono, 2023).

Electromagnetic waves are an embodiment of wave interference patterns that occur due to the oscillation of electrical and magnetic fields, which can generally be solved with Maxwell's equation (Tjia, 1994). The Equations Maxwell's four equations describe the electric and magnetic fields arising from varying distributions of electric charges and currents, and how those fields change in time (Purcell & Morin, 2019). In an empty space where there is no source (charge and current), Maxwell's equation can be written:

$$\vec{\nabla}.\vec{E} = 0 \quad (1)$$

Gauss's law states that the number of electrical field lines that penetrate a covered surface is equal to the amount of charge covered by the surface.

$$\vec{\nabla}.\vec{B} = 0 \quad (2)$$

This equation is also a Gauss law which states that the magnetic field flow that penetrates a closed surface is equal to zero, as well as the absence of a source of magnetic charge.

$$\vec{\nabla} \times \vec{E} = -\frac{\partial \vec{B}}{\partial t} \quad (3)$$

The equation reveals the influence of changing magnetic fields over time or electrical fields arising from changes in magnetic Fields.

$$\vec{\nabla} \times \vec{B} = \mu_0 \epsilon_0 \frac{\partial \vec{E}}{\partial t} \quad (4)$$

This Maxwell equation means that the magnetic field arises as a result of a change in the electrical field, whereas Maxwell's equation in a material where there is no source is:

$$\text{(i) } \vec{\nabla} \cdot \vec{D} = 0 \quad (5)$$

$$\text{(ii) } \vec{\nabla} \cdot \vec{B} = 0 \quad (6)$$

$$\text{(iii) } \vec{\nabla} \times \vec{D} = -\frac{\partial \vec{B}}{\partial t} \quad (7)$$

$$\text{(iv) } \vec{\nabla} \times \vec{H} = -\frac{\partial \vec{B}}{\partial t} \quad (8)$$

For linear and isotropic media apply relationships:

$$\vec{D} = \varepsilon_0 (1 + X_e) \vec{E} = \varepsilon \vec{E} \quad (9)$$

with:
$\varepsilon = \varepsilon_0 (1 + X_e)$ (dielectric constant)
$\vec{H} = \frac{1}{\mu} \vec{B}$
$\vec{B} = \mu \cdot \vec{H}$

For a homogeneous medium, Maxwell's equation is written:

$$\text{(i) } \vec{\nabla} \cdot \vec{E} = 0 \quad (10)$$

$$\text{(ii) } \vec{\nabla} \cdot \vec{B} = 0 \quad (11)$$

$$\text{(iii) } \vec{\nabla} \times \vec{E} = -\frac{\partial \vec{B}}{\partial t} \quad (12)$$

$$\text{(iv) } \vec{\nabla} \times \vec{B} = \mu\varepsilon \frac{\partial \vec{E}}{\partial t} \quad (13)$$

Numerical modeling of electromagnetic waves is an important tool for understanding the interaction of light and matter, and lies at the core of computational electromagnetics (Weichman et al., 2024). The electromagnetic fields in such dielectric media are described by fractional differential equations with time derivatives of non-integer order (Tarasov, 2008). Faraday's Law of induction is often stated as "a change in magnetic flux causes an electro-motive force (EMF)"; or, more cautiously, "a change in magnetic flux is associated with an EMF"(Kinsler, 2020). We recently developed a multiple-choice conceptual survey in mechanical waves. The development, evaluation, and demonstration of the use of the survey were reported elsewhere (Tongchai et al., 2011).

Based on the existing literature and interview results, the conceptual framework model of wave propagation was developed and used to guide the development of a multiple-choice test that targets the assessment of knowledge integration in students' understanding of wave propagation (Xie et al., 2021). The Mechanical Waves Conceptual Survey (MWCS), presented in 2009, is the most important test to date that has been designed to evaluate university students' understanding of four main topics: propagation, superposition, reflection, and standing waves (Barniol & Zavala, 2017).

Method

The methods used in this research are quantitative methods and the research is carried out by providing filling issues that will analyze verbal multirepresentation capabilities, tables and graphs. The research will be carried out at Semarang University using a sample of 50 students. The stage of the study can be seen as in Figure 1. Research procedures through preliminary stages by drawing up a research plan.

Preparing and compiling wave learning modules using the simulation facilities of Physics Education Technology, then compiling evaluation tools that are subject-based with multi-representation verbal approaches, tables and graphs. Validation of learning modules and evaluation tools to determine whether it is worthy of use or not, validation is carried out by 2 experts.

First Revised and then Used for Data Retrieval. Data collection is carried out by providing test instruments in the form of filling questions to students. Data analysis of students' answers, assessments and analyses are calculated using the count of their presentations.

$$N = \frac{\text{Total score obtained}}{\text{Maximum score}} \times 100\% \quad (14)$$

To analyze it can be done with the following criteria:
if $66.68 \leq N \leq 100$: high criteria
if $33.34 \leq N \leq 66.67$: current criteria
if $0 \leq N \leq 33.33$: low criteria

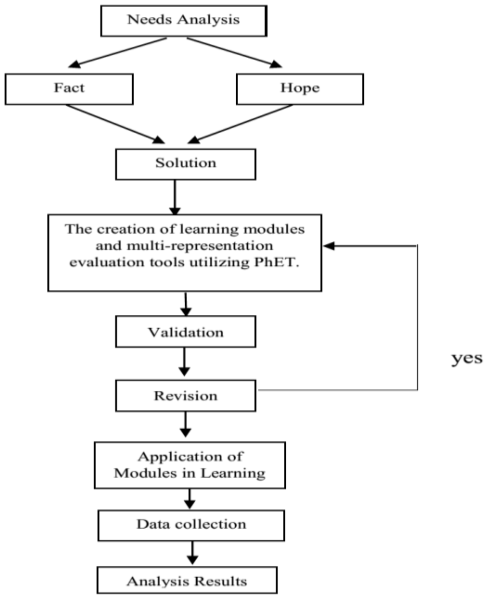

Figure 1. Research methods

Result and Discussion

The data described are the results of student representation skills, the validity data of test instruments and the validation data of modules and evaluation tools. Preliminary research, literary studies are conducted to identify problems related to learning assessment through relevant journals and then to rely on facts in the field.

Table 1. Preliminary Research

Author	Title	Results of Research
Astutik (2021)	Analysis of Verbal and Graphic Multirepresentation Ability of Physics Students on the Concept of Electromagnetic Wave Spectrum	The results of the data obtained that the student's multirepresentation ability analysis on the material High electromagnetic wave characteristics on the verbal representation format
Sari et al. (2021)	Development of E-Learning Module Based on Multiple Representation Integrated with GeoGebra	The effectiveness shows from the Mann Whitney U test shows that there is a difference in the average value of pre-test and post-test participants learners, which can be summarized that the module is effective to be applied

Table 2. Recapitulation of Validation of Test Instruments by Experts

Aspect	Average presentation (%)	Advice
Material	93	I'm trying to find a complex solution
Construction	94	It's good
Language	92	Fixed the principle of capital writing on some issues

Validation of test instruments carried out through an expert or expert that covers material, construction and language aspects. Obtained results like Table 2. Multi-representation capability data. This data is obtained from queries tested according to the query type. The calculation results can be seen in Table 3.

Based on the results of data analysis obtained results on small-scale tests presenting the lowest average in representing mathematics into its physical sense and representing from images, mathematical then into the physical sense. The graph is shown in Figure 2.

Table 3. Multirepresentation Ability Presentation

Question type	Multirepresentation percentage (%)
Mathematical – Verbal	60
Mathematical – Physical	50
Mathematical – Picture	75
Mathematical	75
Mathematical – Physical – Verbal	52
Physical – Mathematical	55
Picture – Mathematical – Physical	50

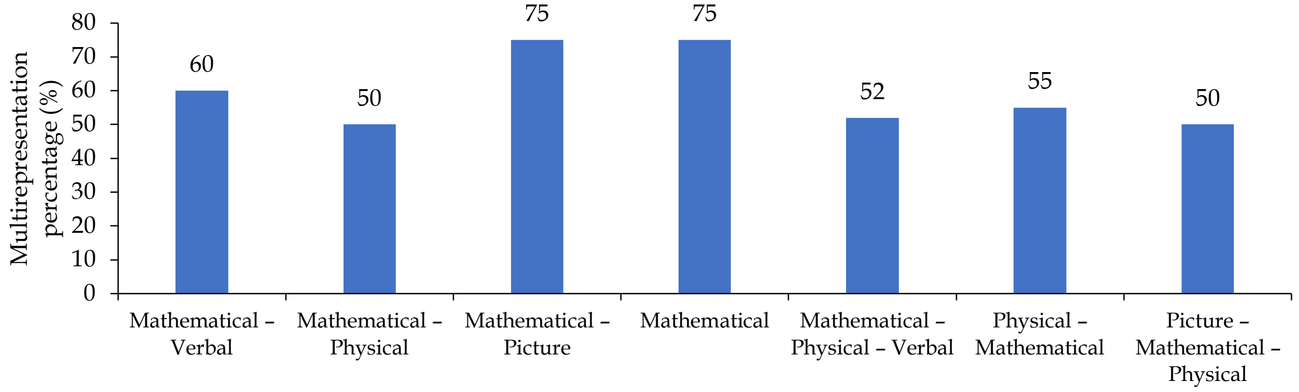

Figure 2. The graph of multirepresentation

Evaluation Stage Results

Multirepresentation Capacity Data. Data from known multirepresentational capabilities that start answering the type of question is obtained from the calculation of the average presentation of questions that can be answered correctly by the student on the question type. The calculation results are shown in Table 4. The result is if cast in the form of a graph like Figure 3.

The multi-representation test instrument developed consists of seven descriptive questions. The subjects developed have been tested on a small scale and on a large scale, and prior to being tested have been validated by experts to know from the point of view of material, construction and language. In terms of material is given input for the subject being tried to find a complex solution, then in terms of language is asked to improve the writing with use according to EYD. From the advice and input have been made improvements for the issue to be used.

The stage of validity test or small scale test obtained the lowest result is for mathematical-physical representations and mathematic-Physical images i.e. at the figure 50%. At the time of calculations using mathematics and then have to explain into the form of physics will feel difficulty, as well as of the images then calculated with the use of mathematically and explained into the physical sense, students have difficulty.

Table 4. Multirepresentation Ability Presentation

Question type	Multirepresentation percentage (%)
Mathematical – Verbal	70
Mathematical – Physical	65
Mathematical – Picture	80
Mathematical	80
Mathematical – Physical – Verbal	70
Physical – Mathematical	70
Picture – Mathematical – Physical	75

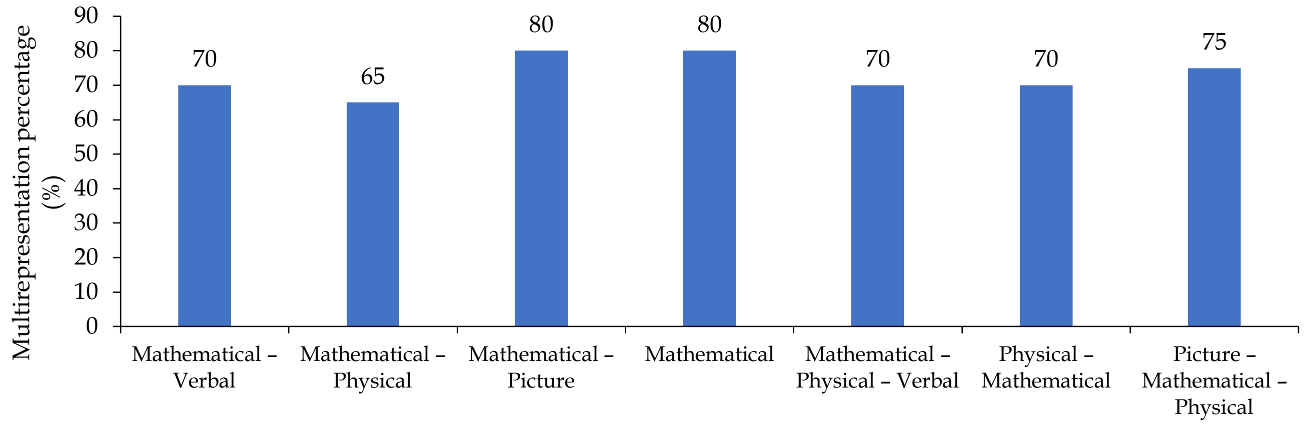

Figure 3. The graph of multirepresentation

Multi-representation test results of each subject were improved from small-scale trials. As an example of a multi-representation of mathematical-physical images, which was initially tested on a small scale of 50% and then improved by 75% using PhET start help. Using this PhET simulation, students can perform simulations and modify parameters so that they can differentiate the results obtained. Changed amplitudes or the number of waves or vibrations will result in frequency, amplitude or equation values. So, from the simulation, students will be able to explain how the physical meaning of a picture and its mathematical equations. On the results of the research also obtained multirepresentation answers that are still low is at the time of its physics, in order to facilitate it can use some simulation applications such as PhET that can help students understand the physical significance by changing some of its parameters.

Conclusion

Based on the results of the research and discussion, the conclusion that can be drawn from this study is that multi-representation test instruments developed through the preliminary phase, validation and evaluation meet the criteria. The conclusion of the study is validation of learning modules and evaluation tools to determine whether it is worthy of use or not, validation is carried out by 2 experts. Validation of test instruments by experts on material aspects averaged 93%, on construction aspects 94% and on language aspects reached 92%, of which results show that the instruments have excellent validity. In the finite scale test, the highest multirepresentation ability is communicating from mathematics to verbal and its mathematical abilities, while the lowest is in the ability to picture to mathematics and physics.

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Author Contributions
I,P. and W. conceived of the presented idea. I, P. developed the theory and performed the computations. P and W. verified the analytical methods. I and W. supervised the findings of this work. All authors discussed the results and contributed to the final manuscript

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Conflicts of Interest
All authors declare that they have no conflicts of interest.

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