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Profile of Mathematical Representation Ability of Students to Solve Mechanical Wave Matter Physics Problems

Dita Fitriani[1], I Ketut Mahardika[1,2,3,4*], Bambang Supriadi[1]

[1] *Physics Education Study Program, Faculty of Teacher Training and Education, University of Jember. Jl. Kalimantan No. 37, Jember, East Java, 68121, Indonesia*
[2] *Science Education Study Program, Faculty of Teacher Training and Education, University of Jember. Jl. Kalimantan No. 37, Jember, East Java, 68121, Indonesia*
[3] *Science Education Magister Study Program, Faculty of Teacher Training and Education, University of Jember. Jl. Kalimantan No. 37, Jember, East Java, 68121, Indonesia*
[4] *Science Education Doctoral Study Program, Faculty of Teacher Training and Education, University of Jember. Jl. Kalimantan No. 37, Jember, East Java, 68121, Indonesia*

Corresponding author. Email:iketutmahardika202@gmail.com

[1]ditafitriani678@gmail.com, [2,3,4]iketutmahardika202@gmail.com, [1]bambangsscmsc@gmail.com

ABSTRACT

Physical Science develops through a series of scientific processes and cannot be understood by memorization, but rather requires understanding concepts so physicists use various forms of representation. This study aims to examine more deeply the ability of mathematical representation of students second science grade of senior high school in solving mechanical wave problems. The research method used is descriptive quantitative. The data collection technique used is a written test consisting of five description questions based on mathematical representations of mechanical wave material, interviews, observations, and documentation. The data obtained from this study are the results of diagnostic tests based on a mathematical representation. The data is processed in the form of percentages and then analyzed and grouped into several categories. The results of the study obtained the average mathematical representation ability of students in solving mechanical wave matter physics problems thanks to the "excellent" category of 68.89%, the "good" category of 9.29%, the "good enough" category of 8.69%, the "not good" category of 1.90%, and 11.24% of students categorized as fail in solving physics problems using mathematical representations of mechanical wave matter. The results of this study are expected to provide information to physics teachers about students' multi-representation abilities based on the ability to solve physics problems in mechanical wave material. The research contribution for schools can provide illustrations of students' multi-representational abilities so that they are expected to be able to improve the quality of physics learning to support students to keep up with the rapid development of science and technology. The next research contribution is can be used as a reference source for similar research, as well as increasing the view of the importance of mastering physics concepts with various forms of representation.

Keywords: Physical Sciences, Problem-Solving, Mathematical Representations.

I. INTRODUCTION

Physics is one of the branches of science that studies natural phenomena related to matter and energy [1]. Physical science is one of the keys to the success of students in adjusting when entering the 21st century [2]. Physics is a science that develops through a series of scientific processes [3]. Physics is not a science that can be understood by memorization but requires reasoning and understanding of concepts [4]. Physicists use various forms of representation to facilitate the analysis of concepts, theories, principles, and laws – laws of nature [5]. Learning physics by representation can help students understand the concepts learned [6]. The purpose of learning physics is to form the ability to reason in students which are reflected in the ability to think critically,

systematically, logically, honestly, and disciplined in solving a problem [7]. Science learning must be balanced with the provision of evaluation questions that can train students to improve thinking skills and develop the ability to reason with the problems given [8]. Solving physics problems has a different presentation or representation format so it cannot be solved using only one form of representation, but requires a varied presentation format [9].

Mathematical representation is the cognitive ability of students in expressing scientific concepts in the form of mathematical symbols, mathematical models, diagrams, tables, graphs, and words as a tool to facilitate the resolution of physics problems in studying physics concepts that affect student learning outcomes [10,11]. Multirepresentation in physics learning is divided into four types, namely image representation, mathematical representation, graph representation, and verbal representation. The limitations of this study will only address students' mathematical representation abilities. As stated on Government Regulation Number 22 of 2006 states the importance of mastering mathematical representation so that students are able to solve problems mathematically [12]. The mastery of concepts owned by students is not only the memorization of mathematical formulas but also influenced by other abilities, one of which is the ability to represent mathematical perceptions of a problem faced [13].

The ability to represent physical processes in various forms of representation is able to stimulate students in finding solutions to physics problems that are considered difficult [14]. Representation plays a role in the process of finding solutions to physics problems in accordance with the problem-solving steps initiated by Heller, including focusing on the problem, describing the problem, planning the solution, implementing the plan, and evaluating the solution [15]. An individual needs a good mathematical reasoning ability in representing mathematical objects [16]. The mathematical representation approach is more often used in physics learning, in line with the opinion of Lindenfield (2002) who states that teachers spend a lot of time-solving physics problems using mathematical equations so that students' mathematical representation ability in solving physics problems is the least problematic [17]. Students' mathematical representation skills have been well-trained because they are accustomed to memorizing formulas in solving physics problems [18]. The operational forms of mathematical representations include students being able to make mathematical models or equations from the represented representations, being able to make conjectures of a number pattern, and being able to make problem-solving by involving mathematical equations [19]. Solving physics problems with varied representations will help communicate thoughts, and deepen and develop students' understanding of a concept [20]. Learning evaluation is an important part of the learning cycle because the results of the evaluation will affect the decision-making process. Through evaluation, teachers can also find out the development of learning outcomes, personality, interests, talents, attitudes, and social relationships of students [21]. The ability to solve physics problems can be used to find out the proper handling of deficiencies in learning [22]. High school physics learning class XI must be mastered well, one of which is waves, because a good understanding of the concept of waves can support students to able to understand other physics materials related to daily life [23]. Mastery of the physics concepts of mechanical wave matter will also help learners when studying optics, quantum mechanics, and electronics. The wave concept is also used as one of the core ideas in the NRC framework [23]. In 2009, a conceptual survey (MWCS) was conducted through a test designed to evaluate learners' understanding of mechanical wave material. Bani (2019) states that mechanical wave matter contains abstract concepts so students have difficulty learning and understanding them compared to the topics of mechanics, kinematics, electricity, and magnetism [24,25].

The previous research related to analyzing the understanding of students' concepts on mechanical wave material conducted at one of the aliyah madrasahs in Jombang showed that the understanding of the concepts of class XI science students was included in the weak category with an average score of 64.6% and experienced misconceptions of 26.9% [26]. This is in accordance with the research that has been carried out previously in 2022 which revealed that the percentage of students' mathematical representation ability of 29.8% is relatively low [27]. Students' ability to solve physics problems is closely related to mathematical representation skills, students who have high mathematical representation skills will find it easier to find solutions to physics problems [11]. The importance of mathematical representation ability for students in studying physics concepts is interested in conducting a more in-depth study related to students' mathematical representation ability in solving mechanical wave matter physics problems. Based on the background and description of the problem, the purpose of this study is to describe the category of mathematical representation ability of students on the second science grade of senior high school based on the ability to solve physics problems in mechanical wave material.

II. METHOD

The method used in this study is descriptive with a quantitative approach. Descriptive research with a quantitative format explains various situations and conditions as well as various number-based variables, ranging from data collection, data interpretation, and interpretation of data [28, 29, 30]. Descriptive analysis is a type of data analysis that aims to present the characteristics of a sample and each research variable [31]. The design in this study used a survey with a cross-sectional survey design. The research place is determined by the purposive sampling area method, namely at one of the Senior High Schools located in Banyuwangi Regency and is carried out during the even semester of the 2022/2023 school year, with the research sample are several groups of students on second science grade, including first science class totaling 36 students, second science class totaling 35 students, and fourth science class totaling 35 students. The data collection technique used is a written test consisting of five mathematical representation-based description questions on previously taught mechanical wave material, interviews, observations, and documentation. The interview technique was conducted in a structured manner involving 9 students, consisting of representatives of 3 students in each class that was the subject of the study. The study involved three observers when collecting data in schools. The observer is tasked with supervising the attitude of students during the implementation of the test by filling out an observation sheet covering three indicators including honesty, discipline, and responsibility. Data collection with documentation techniques is carried out during the implementation of tests, interviews with teachers and students, and test results on student answer sheets. Furthermore, student test results are given scores based on the assessment rubric, which is a score of 0 to a score of 4. The percentage of the student's mathematical representation ability score is calculated using the following formula:

$$NP = \frac{R}{SM} \times 100\% \quad (1)$$

Information:

NP = Percentage of students' multi-representation ability scores
R = The score of the question answered correctly
SM = Ideal Maximum Score of a given test

Then the percentage of student scores is analyzed based on being categorized in the criteria for students' mathematical representation ability. Students are categorized as "excellent" if the percentage value is in the range (80 % <NP≤ 100 %), students are categorized as "good" if the percentage value is in the range (60 % <NP≤ 80 %), students are categorized as "good enough" if the percentage value is in the range (40 % <NP≤ 60 %), students are categorized as "not good enough " if the percentage value is in the range (20 % <NP≤ 40 %), students are categorized as "very bad" if the percentage value is in the range (0 % <NP≤ 20 %), and students are categorized as "fail" if the percentage score (NP= 0%) [32]. Each category will be described for its mathematical representation ability based on the mathematical representation scoring rubric.

III. RESULTS AND DISCUSSION

The mathematical representation ability on second science grade of senior high school based on the ability to solve mechanical wave matter physics problems is obtained from the results of the mathematical representation test given to students on second science grade of senior high school 1 Cluring. The data on the results of the mathematical representation test given to students on second science grade of senior high school 1 Cluring are presented in table 2.

Question Number	Problem Indicators	Score	Category	First Science Class		Second Science Class		Fourth Science Class	
				N	%	N	%	N	%
1.	Calculates the wavelength (λ) and rapid propagation of the (v) wave of the rope on the transverse wave event	4	SB	35	97,22	33	94,29	29	82,86
		3	B	0	0	2	5,71	5	14,29
		2	CB	1	2,78	0	0	0	0
		1	KB	0	0	0	0	0	0
		0	G	0	0	0	0	1	2,86
	Calculates the value of	4	SB	30	83,33	32	91,43	31	88,57

	frequency (f) and rapid propagation of wave (v) at transverse wave events	3	B	0	0	2	5,71	2	5,71
		2	CB	0	0	1	2,86	1	2,86
		1	KB	0	0	0	0	0	0
		0	G	6	16,67	0	0	1	2,86
3.	Calculates the period (T), wavelength (λ), and frequency (f) at longitudinal wave events	4	SB	33	91,67	34	97,14	30	85,71
		3	B	0	0	1	2,86	1	2,86
		2	CB	0	0	0	0	1	2,86
		1	KB	0	0	0	0	0	0
		0	G	3	8,33	0	0	3	8,57
4.	Calculates the magnitude of the three smallest angles at the event of constructive and destructive interference.	4	SB	12	33,33	17	48.57	9	25,71
		3	B	2	5,56	7	20	10	28,57
		2	CB	8	22,22	6	17,14	7	20
		1	KB	0	0	1	2,86	0	0
		0	G	14	38,89	4	11,43	9	25,71
5.	Calculating the deviation angle of the laser beam after passing through a prism at the light dispersion event	4	SB	10	27,78	10	28,57	20	57,14
		3	B	7	19,44	7	20	3	8,57
		2	CB	5	13,89	9	25,71	7	20
		1	KB	1	2,78	5	14,29	3	8,57
		0	G	13	36,11	4	11,43	2	5,71
Total				**36**	**100**	**35**	**100**	**35**	**100**

Information :
N = Number of students
% = Percentage
SB = Excellent
B = Good
CB = Good Enough
KB = Not Good Enough
G = Fail

The results of the mathematical representation test on second science grade of senior high school 1 Cluring student in first science class there were 24 students with excellent categories, 2 students with good categories, 3 students in the category were quite good, and 7 students were categorized as failing because they did not answer the questions. On second science class, there are 25 students with excellent categories, 4 students with good categories, 3 students in the category of being quite good, 1 student in the category of not being good, and 2 students in the category failing because they did not answer the questions. On fourth science class, there are 24 students with excellent categories, 4 students with good categories, 3 students in the category of being quite good, 1 student in the category of not being good, and 3 students in the category failing because they did not answer the questions. The following is presented as a graph of the average comparison of mathematical representation capabilities in each category, which can be seen in figure 1.

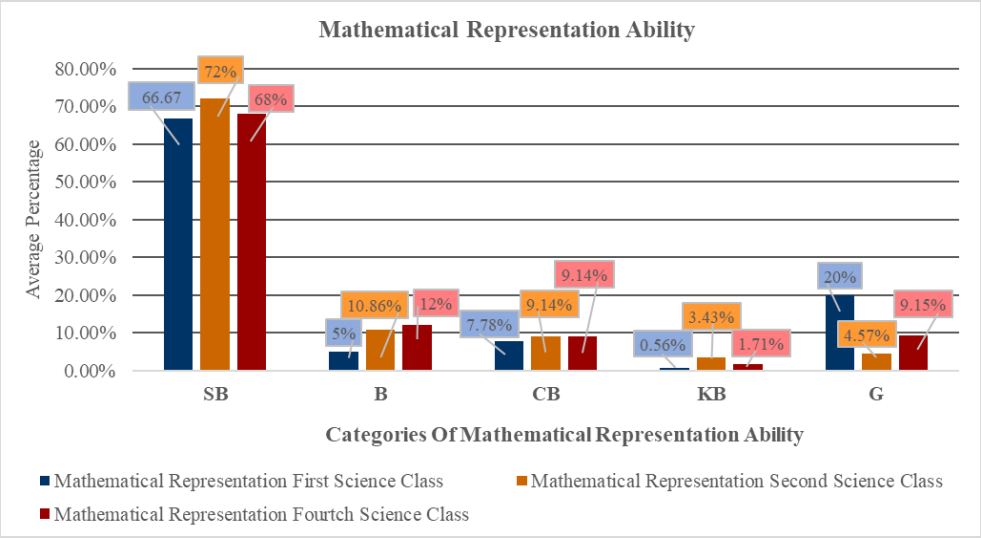


Fig. 1 Comparison Average Percentage of Students' Mathematical Representation Ability

The mathematical representation ability of first science class students based on the ability to solve physics problems is very good by 66.67%, good categories by 5%, categories are quite good by 7.78%, categories are not good by 0.56% and 20% of students are categorized as failing to solve mathematical representation questions. The mathematical representation ability of second science class students based on the ability to solve physics problems is very good by 72%, good categories by 10.86%, categories are quite good by 9.14%, categories are not good by 3.43% and 4.57% of students are categorized as failing to solve mathematical representation problems. Mathematical representation ability of fourth science class students based on the ability to solve physics questions, the category is very good at 68%, the category is good at 12%, the category is quite good at 9.14%, the category is not good at 1.71% and 9.15% of students are categorized as failing to solve mathematical representation questions. Furthermore, the percentage of mathematical representation ability students on second science grade will be compared based on the category of mathematical representation ability of each class that is the subject of research.

Mathematical representation ability students on second science grade of senior high school 1 Cluring based on the ability to solve mechanical wave matter physics problems in the "excellent" category, second science class occupies the highest position with an average percentage of 72% and first science class occupies the lowest position with an average percentage of 66.67%. In the "good" category, the fourth science class occupies the highest position with an average percentage of 12%, and the first science class occupies the lowest position with an average percentage of 5%. The data was covered by the results of an interview with one of the students who revealed that they did not have any difficulties when doing mathematical representation questions because they were used to memorizing formulas to solve physics problems. Based on the results of an interview with one of the students related to solving the problem through a mathematical representation approach, it was revealed that

> "It is not difficult because I often do mathematical physics questions, it is difficult when we forget or even do not know which formulas should be used because some formulas are difficult to understand so we must first understand the problems presented and if we are not careful the final result will be wrong" (interview, PDZ / Second Science Class, January 18, 2023).

In the "good enough" category, the second science class and fourth science class have an average percentage of 9.14% higher than the first science class which has an average percentage of 7.78%, in the "not good" category, the second science class occupies the highest position with an average percentage of 3.43% and first science class occupies the lowest position with an average percentage of 0.56%, while in the "failed" category, first science class occupies the highest position with an average percentage of 20% and second science class occupies the lowest position with an average percentage of 4.57%. The results of this study are in line with research conducted by Hasbullah in 2018, namely the ability of mathematical representation of students has been trained both in the learning process and in solving physics problems because they are used to memorizing formulas [18]. In the results of an interview related to solving problems based on mathematical representation, one of the students revealed that

"It's quite easy because I really like physics and am used to doing physics questions with mathematical representations, it's just that I need to understand the meaning of the questions so that I can correctly determine the equations used to answer the questions and do calculations carefully so that the final result is not wrong" (Wawancana, AES / Fourth Science Class, January 17, 2023).

The most common mistake made by students in solving mechanical wave problems based on mathematical representations is not being careful in doing mathematical calculations, especially on decimal numbers because they do not convert units in the form of SI. Dienyati, Werdhiana, and Wahyono (2020) revealed that the difficulties experienced by students when doing calculations will affect all calculations so the final results obtained experience errors [33]. Some students experienced errors in changing formulas and incorrect conversion of units, causing the final result to be wrong and only gave units at the end of the answer. The following is an example of student work when doing physics questions using a mathematical representation of mechanical wave matter that scores 1 to 4 on question number 3 in calculating the wave period (T), wavelength (λ), and wave frequency (f).

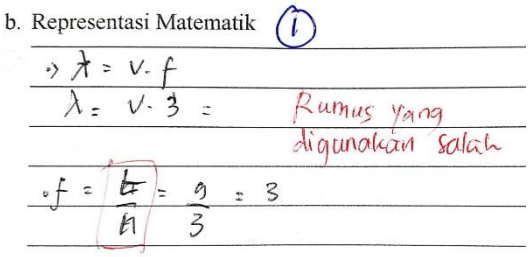


Fig 2. Sample For Score 1

The results of student work in figure 2 show that students get a score of 1 because they used the wrong formula so that the answers given are not meaningful. The mathematical equation that students use is $f = \frac{t}{n}$ when calculating the magnitude of the wave frequency, it should use the equation $f = \frac{n}{t}$, which causes the final result to be wrong too. Therefore its mathematical representation ability is categorized as "not good".

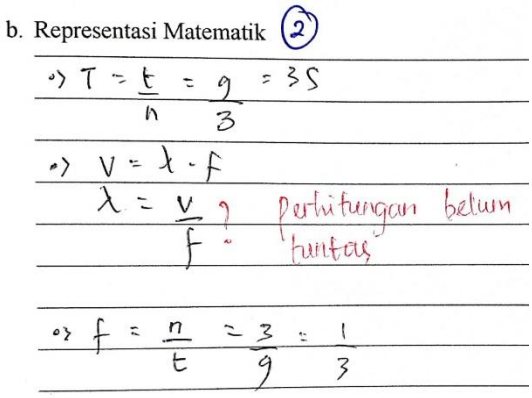


Fig. 3 Sample For Score 2

The results of the student's work in figure 3 show that the student scored 2 because the student had used the formula correctly but did not perform calculations completely on the wavelength (λ) and wave frequency (f) sections, so his mathematical representation ability was categorized as "quite good".

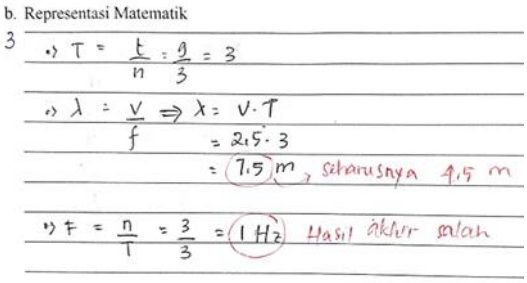


Fig. 4 Sample For Score 3

The results of the student's work in figure 4 show a score of 3 because the student is not careful in substituting the known amount in the question, namely the student's v grade writes the number 3 where it is wrong which should be 1.5 and wrong in writing the formula of the wave frequency, the student writes the formula $f = \frac{n}{T}$. Where it is wrong which should be $f = \frac{n}{t}$. Students are also less meticulous in doing calculations causing the final result to be incorrect, so their mathematical representation ability is categorized as "good".

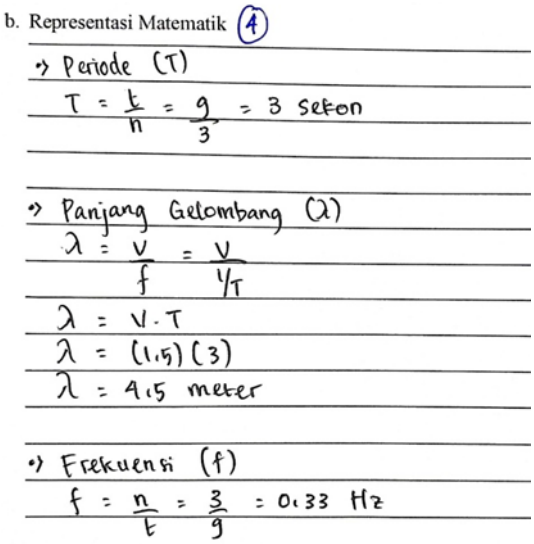
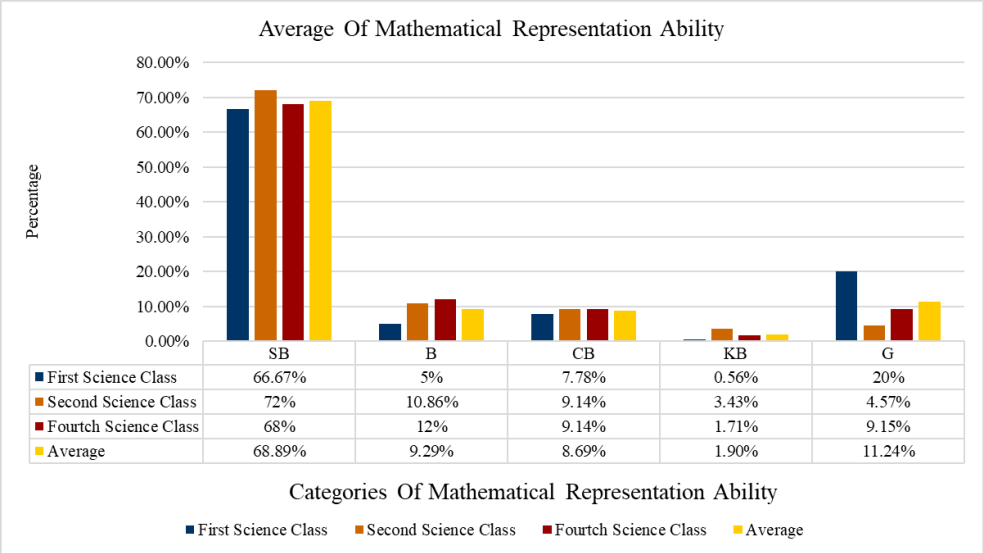


Fig. 5 Sample For Score 4

The results of student work in figure 5 show that the score of 4 student work results is considered correct because it is correct in using formulas, complete in doing calculations, and the final results obtained are also correct. Therefore its mathematical representation ability is categorized as "excellent". Meanwhile, students' mathematical representation ability is categorized as "fail" if the student scores 0, meaning that they are not capable at all of solving mechanical wave matter physics problems using mathematical representations.

The most perfectly answered questions, namely 4, are numbers 1, 2, and 3, because they have been able to find solutions, use formulas correctly and perform complete mathematical calculations such as wavelength (λ), wave frequency (f), and wave period (T). Meanwhile, the most failures experienced by students when answering question number 4 are because students still feel unfamiliar with the problems presented. Students have not been able to distinguish the mathematical equations used in constructive interference and destructive interference. Mathematical representation is able to translate, express, visualize, and symbolize an idea, idea, and mathematical concept in a problem faced by students in order to get a clear meaning in various forms so as to be able to provide an understanding and alternative solution to the problem at hand [34]. Mathematical representation is very important in the physics learning process because it can help students in finding solutions to problems that are being faced and are considered complex and difficult to solve simply if students have good strategies and mathematical representation skills [35]. The following is presented as a graph of the average mathematical representation ability of students on second science grade of senior high school 1 Cluring in each category in solving mechanical wave matter physics problems, which can be seen in figure 6.



	SB	B	CB	KB	G
First Science Class	66.67%	5%	7.78%	0.56%	20%
Second Science Class	72%	10.86%	9.14%	3.43%	4.57%
Fourtch Science Class	68%	12%	9.14%	1.71%	9.15%
Average	68.89%	9.29%	8.69%	1.90%	11.24%

Fig. 6 Average Mathematical Representation Ability Students of Senior High School 1 Cluring

In this study, the ability of mathematical representation of the second science class occupies the highest position as evidenced by the average percentage of the "excellent" category by 72% greater than first science class and fourth science class. According to figure (1) the highest category of "fail" experienced by first science class was 7 students with an average percentage of 20%. The results of this study are supported by the opinion of Kurniasari and Wasis (2021) which states that a student's multi-representational ability is related to the mastery of concepts owned by each student [36] which means that the mastery of concepts of second science class students is higher than first science class and fourth science class. The results of this study are supported by the results of observation sheets assisted by three observers including aspects of honesty, discipline, and responsibility of students on second science grade of senior high school 1 Cluring during the implementation of the test. The observation results show that first science class has a percentage of 91.67% and second science class has a percentage of 100% including in the very good category. Meanwhile, fourth science class has a percentage of 83.33% which is a good category. The results of observations on the disciplinary aspect show that first science class has a percentage of 91.67%, second science class and fourth science class have a percentage of 100% including in the excellent category. The results of observations on the aspect of responsibility show that first science class has a percentage of 83.33% which is good category, second science class and fourth science class have a percentage of 91.67% including the excellent category.The results of this study have a greater percentage of students' mathematical representation in the "excellent" category and in the "fail" category smaller than Hardianti and Effendi's (2021) research which revealed that the percentage of students' mathematical representation ability in the high category was 18.18%, and in the low category was 27.28% [37]. The results of this study are expected to provide information to physics teachers about students' multi-representation abilities based on the ability to solve physics problems in mechanical wave material on second science grade of senior high school 1 Cluring so that teachers can find out the types of methods, strategies, and approaches that can be used to improve students' multi representation ability in finding solutions to physics problems. The research contribution for schools can provide illustrations of students' multi-representational abilities so that they are expected to be able to improve the quality of physics learning to support students to keep up with the rapid development of science and technology. The next research contribution is can be used as a reference source for similar research, as well as increasing the view of the importance of mastering physics concepts with various forms of representation.

IV. CONCLUSION

The category of mathematical representation ability of students on second science grade of senior high school 1 Cluring in Banyuwangi Regency based on the ability to solve physics problems in mechanical wave matter has an average in the "excellent" category of 68.89%, in the "good" category of 9.29%, in the "good enough" category of 8.69%, in the "not good" category of 1.90%, and 11.24% of students categorized as failing in solving physics problems of mathematical representation of mechanical wave matter. So the ability of mathematical representation of students based on the ability of solving physics problems on second science grade of senior high school 1 Cluring is generally included in the excellent category. Based on the results of the

study, it can be argued that the theoretical implications are that the ability of students' mathematical representation depends on the ability of physics teachers during the learning process. It is hoped that the teacher can teach the entire mechanical wave material to students, so that students master the concept of mechanical waves as a whole. The practical implication in this research is the importance of mastering physics concepts through mathematical representations because it is able to facilitate when learning physics concepts that can affect student learning outcomes. This research suggestion is aimed at physics teachers and prospective physics teachers should use the entire representation format during the learning process so that when students encounter multi-representation based questions, students are able to do well and are not focused on memorizing formulas alone. Advice for students should learn to understand physics concepts as a whole and not only focus on memorizing formulas to solve a physics problem.

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