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## The validity and practicality of the student worksheet using STEM-based multiple representations in physics learning

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A promotional banner for the 240th ECS Meeting. The banner features a colorful striped border at the top. On the left, the ECS logo is displayed in a green circle. To its right, the text reads "240th ECS Meeting" in large blue font, followed by "Oct 10-14, 2021, Orlando, Florida" in a smaller black font. Below this, it says "Register early and save up to 20% on registration costs" in bold black text, and "Early registration deadline Sep 13" in a smaller black font. At the bottom left, there is a red "REGISTER NOW" button. On the right side of the banner, there is a photograph of a diverse group of people in a professional setting, with a man in a white shirt and tie clapping and smiling.

# The validity and practicality of the student worksheet using STEM-based multiple representations in physics learning

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**Abstract.** The objective of this research was to produce a valid and practical student worksheet using Science Technology Engineering and Mathematics (STEM)-based multiple representations and integrated with twenty first century learning in vibration and wave topic. This research used Research and Development (R & D) method by following 4-D model steps. 15 sample students of grade XI were taken with random sampling. Research instruments were validation sheets, student worksheet implementation observation sheets, and questionnaires. Data were analyzed descriptively and qualitatively. The result showed that the student worksheet by using STEM approach based on integrated multiple representations and integrated with twenty first century learning was: 1) valid by content with average score of 85.41 and valid by construct with average score of 83.88; 2) practical to use in vibrations and waves learning materials and it was shown by average student worksheet implementation by above 80% and 86.66% positive students' responses to the student worksheet.

**Keyword:** Student worksheet, STEM approach, multiple representations.

## 1. Introduction

In learning Physics, students should not only learn the product, but there needs to be learning activities that involve students in the process of how a product can be produced through several experiments. Doing experiment activities would train students to conduct research, to train students think creatively and critically, and this is referred to high order of thinking skill (HOTS). HOTS has an important role in physics learning in improving the ability to solve complex and complicated problems [1], Because physics concepts are sometimes difficult to visualize and involve complex mathematical calculations [2]. In learning physics, students also often face complex mathematical formulas in problem solving, in addition to a good understanding of the natural events and phenomena being studied. Mastering HOTS means that students not only master the skills to memorize, understand, and implement knowledge, but students also have the ability to interpret, analyze, and manipulate information so that students find solutions to learning problems, even in the real world [3]. In learning, students must be able to differentiate ideas or notions in detail and clearly, to have good arguments, to be able to solve problems, to be able to modify explanation, to be able to make hypothesis and understand about complex things to be clearer [4]. HOTS concerns how to improve student's thinking ability to higher level, especially related to critical thinking ability to accept various types of information, to think creatively to solve a problem by using acquired knowledge, and to make decisions in complex situations [5]. There is a mutual correlation between HOTS and problem solving ability. HOTS is able to improve student's problem solving ability, and oppositely the problem solving ability strengthen student's skill to think in



higher order [6]. The same notion is suggested by [7] that HOTS is a thinking ability by involving complex problem solving, detecting correlations, and incorporating new information with already known information.

The physics concept understanding holds an important role for physics problem solving. A lower physics understanding would make a student difficult to solve problem, even more in a more complex and complicated problem [8]. An important issue to address in teaching and learning process is the correlation between concepts in an event. The learners would learn better when they are interested to the teaching and learning process. If the learners are not interested to the delivered learning material, they would not learn it [9]. Overcoming problem to face in physics learning requires learning experience development and to associate between learning material and problem to face and to use learning source properly [10]. The student's thinking skill and problem solving ability are expected to improve by using learning materials. One of learning materials able to train students to improve skill of higher order thinking and problem solving is by using student worksheet. Student worksheet is a proper alternative learning for learners to help them adding information concerning the concept to learn through systematic learning activities. The benefits of student worksheet are that the student worksheet is able to improve student's activities in learning process and able to help teachers guiding students to find out concepts through their activities. In addition, the student worksheet is used to generate student's interest in following learning.

The meet the objective of physics learning in twenty first century, student worksheet or a material suitable for today condition is required. A student with higher academic ability would also have higher thinking speed [11]. An effort can be done to overcome problem concerning lower student's learning result in physics subject is by upgrading learning method and model to use in student worksheet, to provide an emphasize in a learning that makes students to be interested into the delivered materials [12]. An effort possible to do in overcoming the problem of lower student's learning result in physics subject is to update learning method and model to use in the student worksheet, to emphasize a learning that make students to be interested to the delivered materials [12]. One of physics learning approaches is *Science Technology Engineering and Mathematic (STEM)* approach based on multiple representations as a solution alternative for learning in 21<sup>st</sup> century. A STEM based education is a learning education used to create human resources that are able to reason, think critically, be logical and systematical [13]. STEM learning is believed to be able to create creative, critical and active students in doing observations. This is because in STEM approach students are guided to do scientific activities such as observing, trying, analyzing and communication observation result to classmates [14]. STEM also guides students to use technology, design a product, and use mathematics as a language to explain a phenomenon or natural event. Learning with the STEM approach can transfer skills, school culture and rigorous instruction across all subjects [15]. By STEM education implementation, student's scientific thinking process for a problem to solve can be developed [16] and student can acquire skill in applying scientific knowledge where it becomes one of STEM demands [17].

STEM based student worksheet is a learning approach by using inter-discipline approaches where its implementation is done by using problem-based active learning. STEM learning guides students to observe, ask questions, try, analyze, and communicate and integrate literacy ability, knowledge proficiency, skill and attitude, and mastery of technology which are the characteristics of 21<sup>st</sup> century learning. Twenty-one century learning, such as thinking skill that must be owned by students, consists of scientific creativity and innovation [18-20], critical thinking, collaboration skill, communication, literacy and problem solving [21-23].

The use of STEM in learning is not enough because students in a classroom have various learning abilities and styles, so that STEM approach must be combined with another suitable strategy; the multiple representations. Multiple representations can help students to improve their understanding and to think about abstract concept [24]. Meanwhile, not only multiple representation application improves concept understanding, but it also improves problem solving ability and critical thinking skill [25].

Multiple representations is very helpful in the process of finding answers of physics problems as it is stated in the five steps of problem solving suggested by Heller [26]. Multiple representations ability is an ability to interpret and implement various representations in explaining a physics concept or a problem in physics [27].

The development of student worksheet with STEM-based multiple representation integrated with 21st century learning was designed to vibrations and waves learning materials in physics subject. Development of student worksheets using the STEM approach, where each STEM step is explained in multiple representations and is integrated with 21st century learning, such as observing, trying, asking, analyzing, communicating and collaborating. Student worksheets designed with a multiple representation-based STEM approach and integrated with 21<sup>st</sup> century learning is expected to eliminate differences in student learning styles in increasing HOTS and problem solving.

The initial research result through questionnaires showed that students considered vibration and wave topic was difficult to understand besides magnet and electricity materials. The problem in this research was how to develop a valid and practical student worksheet with STEM-based multiple representations integrated with twenty first century learning in physics learning.

## 2. Research Method

This research used Research and Development (R & D) method by following 4-D model; Step 1 *define* – to determine and define student's needs [28] such as student's need analysis, material characteristics, assignments, curriculum studying, formulating objectives, and interviews with informants; Step 2 *design* – to design student worksheet prototype and its supporting learning media such as composing story board for student worksheet writing, making lesson plan, questionnaire, observation sheet, and validation sheet. Step 3 *develop* – used to draft the student worksheet according to the design; Step 4 *disseminate* – used to test student worksheet practicality with a limited field test, by using a classroom containing of 15 grade XI senior high school students. The research flow is shown in Figure 1.

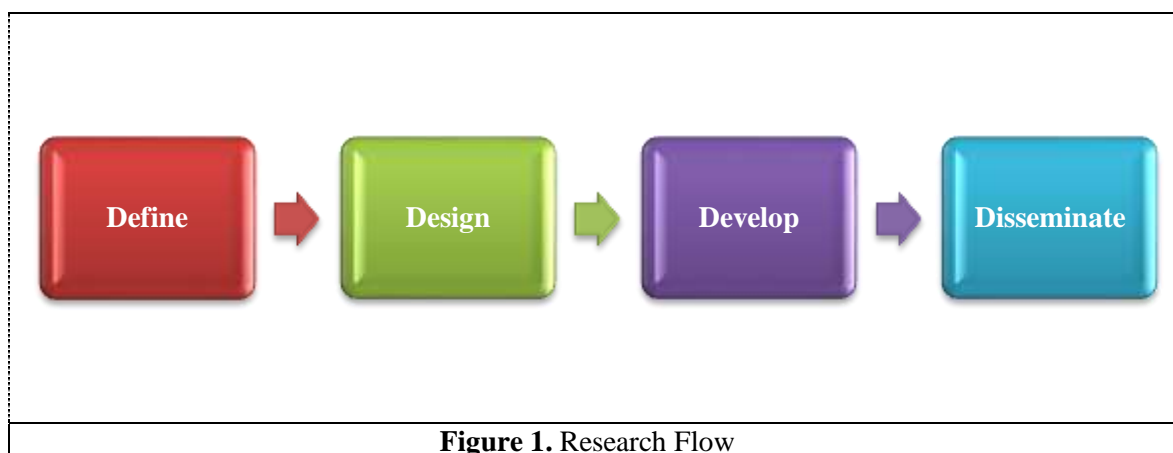


Figure 1. Research Flow

The research instrument was in the form of an observation sheet on the application of student worksheets in learning and student response questionnaires about the use of student worksheets. Observation data on the implementation of the student worksheets and student responses in using the worksheets were analyzed descriptively.

## 3. Result and Discussion

### 3.1. Research Result

Research result and development is grouped into 2; student worksheet validity and practicality.

### 3.1.1. Student worksheet validity.

The student worksheet was validated by three experts in physics. There are 2 criteria in student worksheet validity; the validity of content and construct. The result of content and construct validation results are shown in Table 1.

**Table 1.** The content and construct validities of STEM-based multiple representation student worksheet integrated with 21st century learning

Assessment aspects	Content validity			Average	Construct validity			Average
	Validator				Validator			
	1	2	3		1	2	3	
Material structure	85.83	83.50	82.00	83.78	82.00	81.17	87.5	83.88
Social system	85.17	88.75	86.50	86.81	82.33	84.67	83.5	83.15
Reaction principle	87.33	85.50	88.33	87.06	88.33	83.33	83.17	83.06
Supporting system	85.00	86.50	85.67	85.72	85.67	85.50	82.67	83.03
Nurturant effect	83.50	85.50	82.00	83.67	82.00	84.78	82.54	83.21
Average	85.37	85.95	84.90	85.41	84.07	83.89	83.88	83.88

Table 3 shows that the average of content validity is 85.41 and average construct validity is 83.88, and they belong to valid category. It indicates that the student worksheet for vibrations and waves materials based on STEM and multiple representations that is integrated to 21<sup>st</sup> century learning theoretically is valid.

### 3.1.2. Student worksheet Practicality.

The practicality is based on the implementation in learning and student's response to the student worksheet. Student worksheet implementation is measured with five observation aspects. They are activity steps, social system, reaction principle, supporting system, instructional effect, and nurturant effect. The student worksheet implementation is shown in Table 2.

**Table 2.** Student Worksheet implementation observation result

Observation aspects	Observer		Average
	1	2	
Activity steps	84	86	85.00
Social system	84	82	83.00
Principle of reaction	80	80	80.00
Supporting system	78	80	79.00
Instructional effect	85	82	83.50
Average	82.20	82.00	82.10

Table 2 shows that the average of student worksheet implementation is 82.10 and it belongs to good category. It means that this student worksheet with STEM approach based on multiple representations that is integrated to 21<sup>st</sup> century learning is easy to implement by teachers in vibrations and waves materials learning. Only 2 students (13.33%) responded that the student worksheet was just the same with other student worksheets (indifferent). The student's response to the student worksheet is shown in Table 3.

**Table 3.** Student's response to the student worksheet

Assessment type	Student's response (%)			
	Very helpful (Positive)	Helpful (Positive)	Indifferent (Negative)	Less helpful (Negative)
student Worksheet	33,33%	53,33%	13,33%	0%
Model superiority	1. Helpful in problem solving. 2. Easy to understand concept because represented in some ways. 3. Helpful in developing thinking ability.			
Model weakness	1. Problem solving examples are not much. 2. Sometimes confusing.			
Suggestion	1. Provide more problem solving examples. 2. Presented simpler with more friendly language.			

### 3.2. Discussion

Student worksheets designed with a STEM-based multiple representation student worksheet integrated with 21st century learning was validated by three experts. The content validity average is 85.41 and it belongs to valid category. This student worksheet was composed according to student's curriculum and need and it refers to standard competence and basic competence. According to [29], the validity of a learning material would be obtained when it related to standard of competence and basic competence and learning material compliance that the student must learn and master. The student worksheet also contains of science and technology literacies. The materials in the student worksheet are presented by using STEM approach and every step of STEM is explained with some representations.

The student worksheet was declared valid both by its content and construct. The average construct validation result is 83.88. The construct was also stated to be valid by expert test result with average score  $\geq 70\%$  [30]. This is because material structure in the student worksheet is supported by cognitive and constructive learning theories, not contradictive, mutually related between one sentence and another, enable social interaction and reaction principle to happen, supported by technology, having nurturant effect, and able to motivate students in learning. The student worksheet based on STEM approach and multiple representations meets characteristics of a learning material such as theoretically rational, having learning objectives to obtain, having instructor behaviors and learning environment [8]. Besides having aforementioned characteristics, the student worksheet based on STEM approach and multiple representations also has 5 main elements as they are suggested by [31] that it has: (1) learning steps (syntax), (2) social system, (3) reaction principle, (4) supporting system, and (5) instructional and nurturant effects.

This theoretically valid student worksheet was tested to 15 grade XI senior high school students for practicality test and it was conducted with blended learning. The practicality test was done at physics learning hour. All grade XI sample students were actively involved to do the student worksheet. Practicality student worksheet is indicated by students' positive responses and learning management done by teachers [32]. Student worksheet is said to be practical when it meet assessment criteria in terms of both students' responses and observation result from learning management by teachers. The analysis result of students' positive responses is obtained from questionnaires to determine numbers of students giving either positive or negative responses. Each category in the student worksheet asked in the questionnaire showed more than 80% positive responses from studied subjects. Irsalina and Dwiningsih [33] suggest that a student worksheet is said to be practical when the percentage of assessment result is  $\geq 61\%$ . The result of practicality test showed that the student worksheet was practical with average score of 82.10. It indicated that the student worksheet using STEM approach based on multiple representations and integrated with 21<sup>st</sup> century learning was easy to implement by teachers in physics learning.

During learning, students seemed active to observe, collect data, discuss, and ask question to their teacher and class mates. Multiple representations learning make students to be active questioning and discussing. This research result is affirmed by findings by [34] that multiple representations based

learning make students to be active to pose questions, to write, to listen, and to discuss with classmates. In social system and reaction principle, this student worksheet could be implemented properly. During learning, students felt that the student worksheet was helpful to solve problems because every step of STEM approach was explained with some representations, so that this accommodated varying learning styles the students had. Students were also glad in learning. It was shown that 33.33% students said very happy and 53.33% students said happy to learn using the student worksheet that used STEM-based multiple representation. Only 13.33% students said that the student worksheet was indifferent.

#### 4. Conclusion

Based on the result and discussion, the STEM-based multiple representation student worksheet integrated with 21st century learning was stated to be valid. Content validity was indicated by the average score of 85.41 given by experts and it belongs to valid category. It is because the student worksheet was composed by referring to standard of competence, basic competence, student's need, material characteristics, social system, reaction principle, supporting system, and nurturant effect. Construct validity is indicated by average score of 83.88 and it belongs to valid category. This student worksheet was practical that it is easy to implement by teachers and the average student worksheet implementation score in learning is 82.10. In its implementation, the student worksheet was able to make students doing observation and asking questions to their teachers and classmates. The student worksheet was also able to motivate students to keep on working to solve problems. Students also did not feel depressed during learning, and this was indicated by fact that 86.66% gave positive responses.

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