Five-tier multiple-choice diagnostic test development to identify prospective elementary school teachers' misconceptions about phase transitions

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***Abstract*—This study aims to develop the five-tier multiple-choice diagnostic test to identify prospective elementary school teachers' misconceptions about phase transition using descriptive and verification methods. The subjects include 149 (116 female and 33 male) prospective elementary school teachers in one of the Elementary School Teacher Education Study Programs (ESTESP) in West Java. The stages of the study are as follows: (1) designing a five-tier test instrument to analyze students' misconceptions; (2) validation by experts; (3) instrument testing that was done on prospective teachers who have received phase transition materials; and (4) instrument testing that was done on prospective elementary school teachers who have not received phase transition teaching materials. The obtained data were analyzed descriptively using the percentage technique. In general, the results show that the developed test (FTMC-PT/*five-tier multiple choice-phase transitions*) is ideal for identifying students' conceptions about phase transition. However, further study to develop the test items and to analyze them accordingly as per the item response theory is required.**

Keywords—five-tier test, multiple-choice, misconception, prospective elementary school teachers, phase transition

I. INTRODUCTION

In the last decades, diagnostic tests have grown increasingly popular as a method for collecting data related to a misconception about science learning among students and teachers. As the initiator, Treagust developed a two-tier diagnostic method that explicitly identifies misconceptions and recommends adding a cause tier to determine the students' genuine misconceptions [1]. A two-tier test takes the shape of a system (response choice plus rationale) [2]. To achieve a three-tier, an additional layer of Certainty of Response Index (CRI) was proposed to supplement the limitations of the two-tier method. The three-tier test is formed as answer choice plus rationale plus CRI [3, 4, 5, 6, 7, 8]. Eventually, the three-tier test evolved into a four-tier test. According to Kaltakci-Gurel et al. [9], the four-tier test is a variation of Caleon and Subramaniam's three-tier test [10] that was modified into a four-tier structure [11] for learning mechanical waves concept. The four-tier test is a multi-tiered diagnostic test. Developed a four-tier diagnostic test (Answer Tier, Confidence Rating for Answer Tier, Reason Tier, and Confidence Rating for Reason Tier) [2].

Confidence Rating was added to the three-tier test and evolved into a four-tier test that increases the confidence level of an answer and the explanation for the answer will be more accurate. The four-tier test consists of four-level: multiple-choice questions to test knowledge, answer confidence level at the first level, answer rationale at the first level, and level of confidence (sure or unsure) of the answer's rationale at the third level [2], [9], [12, 13, 14, 15, 16].

The ability to recognize and manipulate concepts in various representations is an indicator of concept understanding [17] because understanding the concept will be closely related to consistency in solving a problem (question). Therefore, students that have grasped the concept will be able to solve the problem using the same principle, despite the differences in the context and representation [18].

There are three levels of material representation: macroscopic, submicroscopic, and symbolic [19]. Differences in knowledge at the submicroscopic level (verbal and visual) were identified in one study [20]. The distinction between verbal and visual aspects suggests that the submicroscopic level should be separated into two groups. It would be necessary given the fact that each level of representation is complimentary and connected, and each level of representation is critical for students to understand [21, 22, 23].

On the phase transition topic, Johnstone [19] suggests a submicroscopic division of verbal and visual, and the use of answer rationale tier, which is a five-tier test (diagnostic test). The five-tier diagnostic test consists of macroscopic level, verbal submicroscopic level, visual submicroscopic level, symbolic level, answer confidence level. It should be noted that because a diagnostic test is based on a conceptual approach [12], the response choices include some distractors resulting from students' preconceptions. These preconceptions are obtained from the literature and previous interview results (teachers and students) [24].

The development of a five-tier multiple-choice diagnostic test to assess prospective elementary school teachers' misconceptions about phase transition (FTMC-PT) is required to be studied. This study is necessary to solve learning issues and difficulties, improve student comprehension, and find a solution to eliminate student misconceptions. However, FTMC-PT has not been found, and the use of representations in diagnostic tests on the prospective primary school teacher students' understanding regarding phase transition has not been investigated. Thus, this study attempts to describe a diagnostic test for the phase transition topic. This test is for prospective elementary school teachers in their third semester assuming they had studied science throughout elementary and high school and had multiple science classes in the first semester. The goal of this study is to develop a valid and accurate five-tier multiple-choice diagnostic test to assess prospective elementary school teachers' misconceptions about phase transition. This study is expected to improve the student's knowledge of educational materials as a learning reflection that may motivate them to take corrective measures and continue their studies.

II. THEORITICAL BACKGROUND

One of the causes of poor students' comprehension is misconception. According to scientific consensus [25-26], misconception is a deviation from the concept of an opinion. In this case, a diagnostic test is required to examine misconceptions [12], [27]. The development of a multiple-choice test to assess students' misconceptions can provide a significant contribution to the science teacher to incorporate research findings into their classroom [1]. These results can be used to determine whether a student has a complete understanding and to determine the correct and incorrect scores [28].

Experts continue to develop the multiple-choice test model by creating the Certainty of Response Index (CRI), which is an instrument that measures the confidence quality of a respondent's answer. CRI is a measure to determine how definite a student's response or answer to a question

[2], [3], [9], [29]. If a student correctly answers a question and the CRI score is greater than 2.5, the student is considered to have a good grasp of the concept. However, if they answer the question incorrectly and the CRI is greater than 2.5, the student has a misconception. Also, those who make a correct or incorrect answer with a CRI of less than 2.5 are categorized as do not understand the concept [30, 31, 32, 33, 34]. As shown in Table 1, Kadarohman, Nahadi, and Mira [26] developed diagnostic test criteria with two alternatives.

TABLE 1. Diagnostic test scoring criteria (Multiple Choice)

No.	Score	Explanation
1	2	If the answers and the rationales are correct or appropriate.
2	1	If the answer is correct, the rationale is wrong, or vice versa.
3	0	If the answer and rationale are wrong.

Based on the previous criteria, respondents with CRI < 2.5 with either correct or wrong answer is categorized as students who do not understand the concept. If those who "do not understand the concept" are given a score of "0," those who have "misconceptions" should be given a score below zero, such as "-1." For conceptual restructuring and minimizing misconceptions, 'more effort' is needed than the previous teaching [33]. Based on Table 1 and the CRI criteria above, the existing assessment criteria were modified, which is presented in Table 2.

TABLE 2**.** Assessment criteria for each item

No.	Answer choices for each Item	CRI Value	Score
1	Correct	> 2.5	2
2	Correct	< 2.5	1
3	Wrong	< 2.5	0
4	Wrong	> 2.5	-1

There are several levels of understanding that can be categorized: categorizing the three groups of understanding: understanding the concepts, misconceptions, and do not understand [26], [35], and categorizing of four groups of understanding: understand, partially understand (not sure with the answers given), misconceptions, and do not understand [30], [32], understand the concepts, do not understand the concepts, misconceptions, and errors [12], [36]. There are also two sections of the five-tier diagnostic test in this study. The first section is a concept-related question (stages 1-4), and the second section is the response certainty level using CRI for the concept-related question. Table 3 shows the categorization of the respondents' levels of understanding about the question items.

TABLE 3. Criteria level of understanding

No.	Answer options of the item	CRI Value	Category
1	All answers are correct	> 2.5	Understand
2	Wrong answer is found	< 2.5	Partial misunderstanding
3	Wrong answer is found	> 2.5	Partial misconception
4	All of the answers are wrong	> 2.5	Misconception
5	All answers are correct	< 2.5	Do not understand
6	All of the answers are wrong	< 2.5	Error

Based on Tables 2, 3, and the representations that have been described previously, a combination of five-tier multiple-choice diagnostic test answers related to phase transition can be developed as illustrated in Table 4.

TABLE 4. Five-tier test answer combination

No.	Answer choices of each stage					Score	Category
	I	II	III	IV	CRI Value		
1	C	C	C	C	> 2.5	8	UC
2	C	C	C	W	> 2.5	5	PUC
	C	C	W	C	> 2.5	5	PUC
	C	W	C	C	> 2.5	5	PUC
	W	C	C	C	> 2.5	5	PUC
	C	C	C	W	< 2.5	3	PUC
	C	C	W	C	< 2.5	3	PUC
	C	W	C	C	< 2.5	3	PUC
	W	C	C	C	< 2.5	3	PUC
	C	C	W	W	> 2.5	2	PUC
	C	W	W	C	> 2.5	2	PUC
	W	W	C	C	> 2.5	2	PUC
	C	W	C	W	> 2.5	2	PUC
	C	C	W	W	< 2.5	2	PUC
	C	W	W	T	< 2.5	2	PUC
	C	W	C	W	< 2.5	2	PUC
	W	W	C	C	< 2.5	2	PUC
	C	W	W	W	< 2.5	1	PUC
	W	W	W	C	< 2.5	1	PUC
	W	C	W	W	< 2.5	1	PUC
	W	W	C	W	< 2.5	1	PUC
3	C	W	W	W	> 2.5	-1	PM
	W	W	W	C	> 2.5	-1	PM
	W	C	W	W	> 2.5	-1	PM
	W	W	C	W	> 2.5	-1	PM
4	W	W	W	W	> 2.5	-4	M
5	C	C	C	C	< 2.5	4	DUC
6	W	W	W	W	< 2.5	0	E

Explanation: UC = Understand the concept; PUC = Partial Understanding of the concept; PM = Partial misconception of the concept; M = Misconception; DUC = Do not understand the concept; E = Error

III. METHOD

Development of a five-tier test for phase transition (FTMC-PT)

A five-tier multiple-choice test about phase transition (FTMC-PT) was developed in this study. This instrument had six items: question 1 was related to melting, question 2 was related to freezing, question 3 was related to vaporization, question 4 was related to condensation, question 5 was related to sublimation, and question 6 was related to deposition. The steps included designing a five-tier test instrument, validation process, instrument testing that was conducted to prospective teachers who had received phase transition materials, and instrument testing that was conducted to prospective elementary school teachers who had not received phase transition materials. The instrument validity test employed a construct validity test from experts using a validation sheet. After the expert validation step was done, the instrument test was conducted. As per the criteria, an item is valid if $r \geq 0.3$ [37] and could be considered reliable if the Cronbach's alpha result showed a coefficient of $\alpha \geq 0.7$ [38].

The subject of the Study

The subjects were 149 (116 female and 33 male) prospective elementary school teachers in one of the ESTESP in West Java.

Data Analysis

All 149 subjects' responses were inputted in Microsoft Excel, then sorted and graded as shown in Table 4. Next, the data were descriptively evaluated using the percentage technique.

IV. RESULTS AND DISCUSSION

The results of the test instrument validation by 3 validators the average is 87.50% (very valid) and the reliability of the test is indicated by the Cronbach Alpha value = 0.774 (reliable). Some of the research results are shown in the following table.

TABLE 5. Descriptive statistics of the test results

Element	Q.1	Q.2	Q.3	Q.4	Q.5	Q.6	score	Final score
Mean	4.84	5.03	3.50	2.99	3.48	2.36	22.20	46.2525
Median	5.00	5.00	3.00	2.00	2	2.00	21.00	43.7500
Mode	5	8	5	2	2	2	27	56.25
Std. deviation	2.712	2.715	2.525	2.623	3.004	3.027	11.505	23.96881
Minimum	-4	-1	-4	-4	-4	-4	-5	-10.42
Maximum	8	8	8	8	8	8	48	100
Sum	721	750	522	445	518	352	3308	6891.62

Table 5 above shows that the highest mean score is 5.03 with a standard deviation of 2.72 on Question 2 (Freezing), while the lowest average score is 2.36 with a standard deviation of 3.03 on Question 6 (Deposition). The highest possible score for all of the questions is 8. All questions have a minimum score of (-4) except Question 2 (Freezing), which has a minimum score of (-1).

TABLE 6. Correct answer percentage (Tier I - IV) and the confidence level of answers of the prospective elementary school teachers using a five-tier test

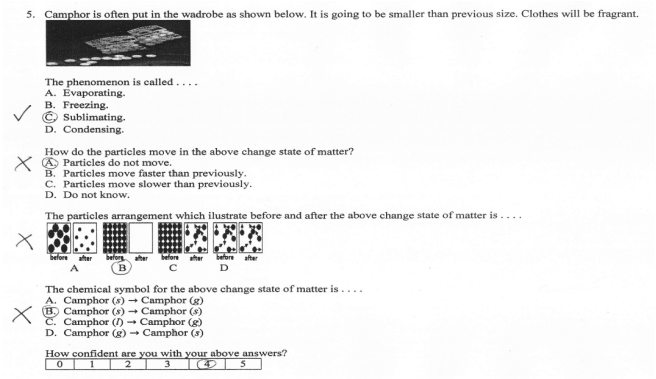
Tier		Q.1	Q.2	Q.3	Q.4	Q.5	Q.6
I		96.6	94.6	93.3	93.3	81.2	60.4
II		78.5	64.4	60.4	48.3	53.7	49
III		49.7	81.9	16.1	26.8	37.6	46.3
IV		76.5	63.8	77.9	63.8	72.5	52.3
V	0	1.34	0.67	2.01	1.34	0.67	2.68
	1	0.67	0.67	0	1.34	0.67	2.68
	2	12.8	12.8	15.4	17.4	16.1	22.1
	3	39.6	32.9	37.6	39.6	43	38.3
	4	28.9	32.9	29.5	27.5	26.2	22.8
	5	16.8	20.1	15.4	12.8	13.4	11.4

Table 6 shows that, for all questions, the percentage of tier III (visual submicroscopic level knowledge) is lower than the other tiers (I, II, and IV). In general, the confidence level of the answers with a value of more than 2.5 (CRI > 2.5) is dominant in all questions.

TABLE 7. The percentage of understanding of prospective elementary school teachers using five-tier test

Phase Transition	UC (%)	PUC (%)	PM (%)	M (%)	DUC (%)	E (%)	Total
Melting	31.54	59.06	2.68	1.34	4.70	0.67	100
Freezing	37.58	55.70	3.36	0.00	2.01	1.34	100
Vaporization	10.74	81.21	3.36	2.01	0.67	2.01	100
Condensation	10.07	73.83	13.42	0.67	0.67	1.34	100
Sublimination	18.79	68.46	8.72	2.68	0.67	0.67	100
Deposition	12.08	59.06	20.13	3.36	2.01	3.36	100

From Table 7, the following information is obtained: (1) Question Number 1 (Melting) has 2.68% partial misconception and 1.34% of misconception; (2) Question Number 2 (Freezing) has 3.36% of partial misconception; (3) Question Number 3 (Vaporization) has 3.36% partial misconception and 2.01% misconception; (4) Question Number 4 (Condensation) has 13.42% partial misconception and 0.67% misconception; (5) Question Number 5 (Sublimination) has 8.72% partial misconception and 2.68% misconception; and (6) Question Number 6 (Deposition) has 20.13% partial misconception and 3.36% misconception. The findings of the five-tier multiple-choice diagnostic test demonstrate that the students had partial misconceptions (PM) on Question 5 and misconception (M) on Question 6. Students who were selected were numbered 4 and 80, the result are as follows.


5. Camphor is often put in the wadrobe as shown below. It is going to be smaller than previous size. Clothes will be fragrant.

The phenomenon is called . . . .
A. Evaporating.
B. Freezing.
C. Sublimating.
D. Condensing.

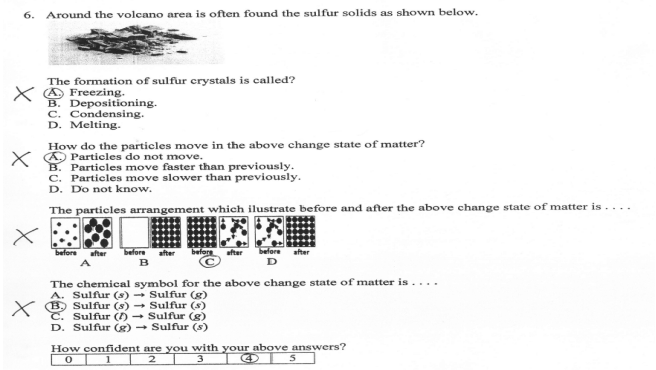
How do the particles move in the above change state of matter?
A. Particles do not move.
B. Particles move faster than previously.
C. Particles move slower than previously.
D. Do not know.

The particles arrangement which ilustrate before and after the above change state of matter is . . . .
A B C D

The chemical symbol for the above change state of matter is . . . .
A. Camphor (*s*) → Camphor (*g*)
B. Camphor (*s*) → Camphor (*s*)
C. Camphor (*l*) → Camphor (*g*)
D. Camphor (*g*) → Camphor (*s*)

How confident are you with your above answers?
0 1 2 3 4 5

Fig. 1. Question 5 (Student Number 4)


6. Around the volcano area is often found the sulfur solids as shown below.

The formation of sulfur crystals is called?
A. Freezing.
B. Depositioning.
C. Condensing.
D. Melting.

How do the particles move in the above change state of matter?
A. Particles do not move.
B. Particles move faster than previously.
C. Particles move slower than previously.
D. Do not know.

The particles arrangement which ilustrate before and after the above change state of matter is . . . .
A B C D

The chemical symbol for the above change state of matter is . . . .
A. Sulfur (*s*) → Sulfur (*g*)
B. Sulfur (*s*) → Sulfur (*s*)
C. Sulfur (*l*) → Sulfur (*g*)
D. Sulfur (*g*) → Sulfur (*s*)

How confident are you with your above answers?
0 1 2 3 4 5

Fig. 2. Question 6 (Student Number 80)

Discussion

The five-tier multiple-choice diagnostic test about phase transition (FTMC-PT) can distinguish between prospective elementary school teachers who may understand the concepts, those who do not understand the concepts, those who have misconceptions, errors, do not understand and have misconceptions about some of the concepts. According to Table 7, the first question (melting) has a higher percentage of "(maybe) do not understand the concept." On the other hand, the sixth question (deposition) has the higher percentage of "(maybe) error." The fourth question (condensation) and the sixth question (deposition) have the percentage of "(maybe) have misconception" of 13.42% and 20.13% respectively. It should be noted that misconception

and partial misconception are not the same. However, if the percentage is greater than 10% of the participants, it can be considered an error [9, 10, 11].

The misconceptions that occur in prospective elementary school teacher students include: in the event of a change in the shape of the particle, it does not experience movement; the motion of particles in the event of freezing, evaporating, and subliming is slower, while in the event of melting, condensing, depositing the motion of particles is faster; The shape and properties of the particles that make up matter are the same as those of the substances they are composed of. These results are in line with previous studies that solid particles are considered to be unable to move at all and the properties of the particles that make up the substance are the same as the substances they are composed of, and changes in form produce new substances [39]. The causes of misconceptions do not only come from educators, but can come from students who have inappropriate preconceptions, using wrong examples [40]. In addition, the status of misconceptions can occur because students have a high level of confidence in the wrong answers [41].

These findings can be used to analyze individual and group issues in learning and also can be utilized as a benchmark for learning improvement. This is in line with the previous study [27] stating that individual-level diagnosis will reflect individual strengths and weaknesses. Meanwhile, the group diagnosis will reflect the strengths and weaknesses of specific sub-concepts based on the test's score scale assessment. This finding is expected to assist educators in reviewing essential content in the learning phase transition concept. It will be easier to arrange a remedial teaching program by studying the needed materials and their achievements. Lecturers can repeat the questions (FTMC-PT) during the class to correct student's errors [41].

According to the findings, prospective elementary school teachers may experience misconceptions. This misconception should be addressed properly to make the learning process run smoothly and will not affect the understanding process of the next concept. This misconception among students motivates lecturers to conduct reflective learning. Categorizing the error types will be beneficial for lecturers to improve the learning process [42]. Students' misconceptions must be rectified so they will not take the misconception as the truth. This is one of the challenges in learning [26]. Misconceptions that are not rectified early will lead to new misconceptions. As a result, students will have a problem learning a concept [27]. It is said that misconceptions are a result of the lack of understanding of prerequisite material [30], [43].

As a result, understanding prerequisite concepts is essential for a student to learn a new concept because the prerequisite concept is crucial to understand the next concept [44]. Students who have misconceptions about a concept are more likely to have misconceptions about the next concept [29], [45]. Students must first comprehend the discontinuous nature of a matter and the dynamic nature of particles as a prerequisite to understand the phase transition concept. According to the previous study [46], students' understanding of particles has to be presented priorly before they learn the sub-microscopic level (structure, composition, and particle movement) in the phase transition class. Students with a thorough understanding of the discontinuous nature of a matter will have little trouble mastering phase transition at the submicroscopic level. Students with a good understanding of this subject are expected to apply what they have learned to other concepts. According to Treagust et al., students must be able to distinguish many forms of representation in science and use their prior knowledge to learn another representation [22]. For example, learning submicroscopic before learning macroscopic or learning symbolic before learning submicroscopic. It would be difficult for students to grasp the new concept without understanding the prerequisite concept [47-48]. To support this, the discontinuous nature of particles and their dynamic qualities as the prerequisite concept must be given and presented in an entertaining way so that students can understand them before the learning phase transition.

In line with Kaltakci-Gurel et al., the results indicate that prospective teachers need to understand the phase transition concept [9]. In addition, the result of this study has an implication about classroom practice, including the development of a diagnostic instrument to identify students' misconceptions about phase transition that can help lecturers in designing and improving their lectures. For example, create a computer program based on diagnostic tests. Because it can help provide feedback to students immediately [49].

The five-tier test developed in this study is based on the representation of the material, so it may take a different form from that proposed by other authors. For example, five tiers are more focused on answer beliefs, reasons for answers, and the relationship between reasons and answer choices [50, 51, 52, 53]. The most important thing is how a diagnostic test can show certain parts of the material that have not been understood by students, and also provide information on how students think in answering a question.

V. CONCLUSIONS

After conducting investigation on the use of representations in diagnostic tests on the prospective primary school teacher students' understanding regarding phase transition, it is found that the developed five-tier multiple-choice diagnostic test is valid and reliable in assessing the students' misconceptions about phase transition in science class. The result of the test could illustrate that the students have misconceptions in the following concepts: 1) in the event of a change in form, the particle does not experience movement; 2) the motion of particles in the event of freezing, evaporating, and subliming is slower, while in the event of melting, condensing, depositing the motion of particles is faster; 3) The shape and properties of the particles that make up matter are the same as those of the substances they are composed of. In addition, a high level of belief in the wrong answer also affects the status of misconceptions. The results of this study have several implications for classroom practice, including making computer programs based on diagnostic tests to facilitate the provision of feedback, and the need for training or debriefing for prospective teachers/teachers related to understanding phase transition. From this research, it is suggested that further research is needed to develop computer-based test items and analyze them according to

item response theory, and training for prospective elementary school teachers/teachers.

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Five-tier multiple-choice diagnostic test development to identify prospective elementary school teachers' misconceptions about phase transitions

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***Abstract*—This study aims to develop the five-tier multiple-choice diagnostic test to identify prospective elementary school teachers' misconceptions about phase transition using descriptive and verification methods. The subjects include 149 (116 female and 33 male) prospective elementary school teachers in one of the Elementary School Teacher Education Study Programs (ESTESP) in West Java. The stages of the study are as follows: (1) designing a five-tier test instrument to analyze students' misconceptions; (2) validation by experts; (3) instrument testing that was done on prospective teachers who have received phase transition materials; and (4) instrument testing that was done on prospective elementary school teachers who have not received phase transition teaching materials. The obtained data were analyzed descriptively using the percentage technique. In general, the results show that the developed test (FTMC-PT/*five-tier multiple choice-phase transitions*) is ideal for identifying students' conceptions about phase transition. However, further study to develop the test items and to analyze them accordingly as per the item response theory is required.**

Keywords—five-tier test, multiple-choice, misconception, prospective elementary school teachers, phase transition

I. INTRODUCTION

In the last decades, diagnostic tests have grown increasingly popular as a method for collecting data related to a misconception about science learning among students and teachers. As the initiator, Treagust developed a two-tier diagnostic method that explicitly identifies misconceptions and recommends adding a cause tier to determine the students' genuine misconceptions [1]. A two-tier test takes the shape of a system (response choice plus rationale) [2]. To achieve a three-tier, an additional layer of Certainty of Response Index (CRI) was proposed to supplement the limitations of the two-tier method. The three-tier test is formed as answer choice plus rationale plus CRI [3, 4, 5, 6, 7, 8]. Eventually, the three-tier test evolved into a four-tier test. According to Kaltakci-Gurel et al. [9], the four-tier test is a variation of Caleon and Subramaniam's three-tier test [10] that was modified into a four-tier structure [11] for learning mechanical waves concept. The four-tier test is a multi-tiered diagnostic test. Developed a four-tier diagnostic test (Answer Tier, Confidence Rating for Answer Tier, Reason Tier, and Confidence Rating for Reason Tier) [2].

Confidence Rating was added to the three-tier test and evolved into a four-tier test that increases the confidence level of an answer and the explanation for the answer will be more accurate. The four-tier test consists of four-level: multiple-choice questions to test knowledge, answer confidence level at the first level, answer rationale at the first level, and level of confidence (sure or unsure) of the answer's rationale at the third level [2], [9], [12, 13, 14, 15, 16].

The ability to recognize and manipulate concepts in various representations is an indicator of concept understanding [17] because understanding the concept will be closely related to consistency in solving a problem (question). Therefore, students that have grasped the concept will be able to solve the problem using the same principle, despite the differences in the context and representation [18].

There are three levels of material representation: macroscopic, submicroscopic, and symbolic [19]. Differences in knowledge at the submicroscopic level (verbal and visual) were identified in one study [20]. The distinction between verbal and visual aspects suggests that the submicroscopic level should be separated into two groups. It would be necessary given the fact that each level of representation is complimentary and connected, and each

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level of representation is critical for students to understand [21, 22, 23].

On the phase transition topic, Johnstone [19] suggests a submicroscopic division of verbal and visual, and the use of answer rationale tier, which is a five-tier test (diagnostic test). The five-tier diagnostic test consists of macroscopic level, verbal submicroscopic level, visual submicroscopic level, symbolic level, answer confidence level. It should be noted that because a diagnostic test is based on a conceptual approach [12], the response choices include some distractors resulting from students' preconceptions. These preconceptions are obtained from the literature and previous interview results (teachers and students) [24].

The development of a five-tier multiple-choice diagnostic test to assess prospective elementary school teachers' misconceptions about phase transition (FTMC-PT) is required to be studied. This study is necessary to solve learning issues and difficulties, improve student comprehension, and find a solution to eliminate student misconceptions. As a result, this study attempts to describe a diagnostic test for the phase transition topic. This test is for prospective elementary school teachers in their third semester assuming they had studied science throughout elementary and high school and had multiple science classes in the first semester. The goal of this study is to develop a valid and accurate five-tier multiple-choice diagnostic test to assess prospective elementary school teachers' misconceptions about phase transition. This study is expected to improve student's knowledge of educational materials as a learning reflection that may motivate them to take corrective measures and continue their studies.

II. THEORITICAL BACKGROUND

One of the causes of poor students' comprehension is misconception. According to scientific consensus [25-26], misconception is a deviation from the concept of an opinion. In this case, a diagnostic test is required to examine misconceptions [12], [27]. The development of a multiple-choice test to assess students' misconceptions can provide a significant contribution to the science teacher to incorporate research findings into their classroom [1]. These results can be used to determine whether a student has a complete understanding and to determine the correct and incorrect scores [28].

Experts continue to develop the multiple-choice test model by creating the Certainty of Response Index (CRI), which is an instrument that measures the confidence quality of a respondent's answer. CRI is a measure to determine how definite a student's response or answer to a question [2], [3], [9], [29]. If a student correctly answers a question and the CRI score is greater than 2.5, the student is considered to have a good grasp of the concept. However, if they answer the question incorrectly and the CRI is greater than 2.5, the student has a misconception. Also, those who make a correct or incorrect answer with a CRI of less than 2.5 are categorized as do not understand the concept [30, 31, 32, 33, 34]. As shown in Table 1, Kadarohman, Nahadi, and Mira [26] developed diagnostic test criteria with two alternatives.

TABLE 1. Diagnostic test scoring criteria (Multiple Choice)

No.	Score	Explanation
1	2	If the answers and the rationales are correct or appropriate.
2	1	If the answer is correct, the rationale is wrong, or vice versa.
3	0	If the answer and rationale are wrong.

Based on the previous criteria, respondents with CRI < 2.5 with either correct or wrong answer is categorized as students who do not understand the concept. If those who "do not understand the concept" are given a score of "0," those who have "misconceptions" should be given a score below zero, such as "-1." For conceptual restructuring and minimizing misconceptions, 'more effort' is needed than the previous teaching [33]. Based on Table 1 and the CRI criteria above, the existing assessment criteria were modified, which is presented in Table 2.

TABLE 2. Assessment criteria for each item

No.	Answer choices for each Item	CRI Value	Score
1	Correct	> 2.5	2
2	Correct	< 2.5	1
3	Wrong	< 2.5	0
4	Wrong	> 2.5	-1

There are several levels of understanding that can be categorized: categorizing the three groups of understanding: understanding the concepts, misconceptions, and do not understand [26], [35], and categorizing of four groups of understanding: understand, partially understand (not sure with the answers given), misconceptions, and do not understand [30], [32], understand the concepts, do not understand the concepts, misconceptions, and errors [12], [36]. There are also two sections of the five-tier diagnostic test in this study. The first section is a concept-related question (stages 1-4), and the second section is the response certainty level using CRI for the concept-related question. Table 3 shows the categorization of the respondents' levels of understanding about the question items.

TABLE 3. Criteria level of understanding

No.	Answer options of the item	CRI Value	Category
1	All answers are correct	> 2.5	Understand
2	Wrong answer is found	< 2.5	Partial misunderstanding
3	Wrong answer is found	> 2.5	Partial misconception
4	All of the answers are wrong	> 2.5	Misconception
5	All answers are correct	< 2.5	Do not understand
6	All of the answers are wrong	< 2.5	Error

Based on Tables 2, 3, and the representations that have been described previously, a combination of five-tier multiple-choice diagnostic test answers related to phase transition can be developed as illustrated in Table 4.

TABLE 4. Five-tier test answer combination

No.	Answer choices of each stage					Score	Category
	I	II	III	IV	CRI Value		
1	C	C	C	C	> 2.5	8	UC
2	C	C	C	W	> 2.5	5	PUC
	C	C	W	C	> 2.5	5	PUC
	C	W	C	C	> 2.5	5	PUC

No.	Answer choices of each stage					Score	Category
	I	II	III	IV	CRI Value		
	W	C	C	C	> 2.5	5	PUC
	C	C	C	W	< 2.5	3	PUC
	C	C	W	C	< 2.5	3	PUC
	C	W	C	C	< 2.5	3	PUC
	W	C	C	C	< 2.5	3	PUC
	C	C	W	W	> 2.5	2	PUC
	C	W	W	C	> 2.5	2	PUC
	W	W	C	C	> 2.5	2	PUC
	C	W	C	W	> 2.5	2	PUC
	C	C	W	W	< 2.5	2	PUC
	C	W	W	T	< 2.5	2	PUC
	C	W	C	W	< 2.5	2	PUC
	W	W	C	C	< 2.5	2	PUC
	C	W	W	W	< 2.5	1	PUC
	W	W	W	C	< 2.5	1	PUC
	W	C	W	W	< 2.5	1	PUC
	W	W	C	W	< 2.5	1	PUC
3	C	W	W	W	> 2.5	-1	PM
	W	W	W	C	> 2.5	-1	PM
	W	C	W	W	> 2.5	-1	PM
	W	W	C	W	> 2.5	-1	PM
4	W	W	W	W	> 2.5	-4	M
5	C	C	C	C	< 2.5	4	DUC
6	W	W	W	W	< 2.5	0	E

Explanation: UC = Understand the concept; PUC = Partial Understanding of the concept; PM = Partial misconception of the concept; M = Misconception; DUC = Do not understand the concept; E = Error

III. METHOD

Development of a five-tier test for phase transition (FTMC-PT)

A five-tier multiple-choice test about phase transition (FTMC-PT) was developed in this study. This instrument had six items: question 1 was related to melting, question 2 was related to freezing, question 3 was related to vaporization, question 4 was related to condensation, question 5 was related to sublimation, and question 6 was related to deposition. The steps included designing a five-tier test instrument, validation process, instrument testing that was conducted to prospective teachers who had received phase transition materials, and instrument testing that was conducted to prospective elementary school teachers who had not received phase transition materials. The instrument validity test employed a construct validity test from experts using a validation sheet. After the expert validation step was done, the instrument test was conducted. As per the criteria, an item is valid if $r \geq 0.3$ [37] and could be considered reliable if the Cronbach's alpha result showed a coefficient of $\alpha \geq 0.7$ [38].

The subject of the Study

The subjects were 149 (116 female and 33 male) prospective elementary school teachers in one of the ESTESP in West Java.

Data Analysis

All 149 subjects' responses were inputted in Microsoft Excel, then sorted and graded as shown in Table 4. Next, the data were descriptively evaluated using the percentage technique.

IV. RESULT AND DISCUSSION

The results of the test instrument validation by 3 validators the average is 87.50% (very valid) and the reliability of the test is indicated by the Cronbach Alpha value = 0.774 (reliable). Some of the research results are shown in the following table.

TABLE 5. Descriptive statistics of the test results

Element	Q.1	Q.2	Q.3	Q.4	Q.5	Q.6	score	Final score
Mean	4.84	5.03	3.50	2.99	3.48	2.36	22.20	46.2525
Median	5.00	5.00	3.00	2.00	2	2.00	21.00	43.7500
Mode	5	8	5	2	2	2	27	56.25
Std. deviation	2.712	2.715	2.525	2.623	3.004	3.027	11.505	23.96881
Minimum	-4	-1	-4	-4	-4	-4	-5	-10.42
Maximum	8	8	8	8	8	8	48	100
Sum	721	750	522	445	518	352	3308	6891.62

Table 5 above shows that the highest mean score is 5.03 with a standard deviation of 2.72 on Question 2 (Freezing), while the lowest average score is 2.36 with a standard deviation of 3.03 on Question 6 (Deposition). The highest possible score for all of the questions is 8. All questions have a minimum score of (-4) except Question 2 (Freezing), which has a minimum score of (-1).

TABLE 6. Correct answer percentage (Tier I - IV) and the confidence level of answers of the prospective elementary school teachers using a five-tier test

Tier		Q.1	Q.2	Q.3	Q.4	Q.5	Q.6
I		96.6	94.6	93.3	93.3	81.2	60.4
II		78.5	64.4	60.4	48.3	53.7	49
III		49.7	81.9	16.1	26.8	37.6	46.3
IV		76.5	63.8	77.9	63.8	72.5	52.3
V	0	1.34	0.67	2.01	1.34	0.67	2.68
	1	0.67	0.67	0	1.34	0.67	2.68
	2	12.8	12.8	15.4	17.4	16.1	22.1
	3	39.6	32.9	37.6	39.6	43	38.3
	4	28.9	32.9	29.5	27.5	26.2	22.8
	5	16.8	20.1	15.4	12.8	13.4	11.4

Table 6 shows that, for all questions, the percentage of tier III (visual submicroscopic level knowledge) is lower than the other tiers (I, II, and IV). In general, the confidence level of the answers with a value of more than 2.5 (CRI > 2.5) is dominant in all questions.

TABLE 7. The percentage of understanding of prospective elementary school teachers using five-tier test

Phase Transition	UC (%)	PUC (%)	PM (%)	M (%)	DUC (%)	E (%)	Total
Melting	31.54	59.06	2.68	1.34	4.70	0.67	100
Freezing	37.58	55.70	3.36	0.00	2.01	1.34	100
Vaporization	10.74	81.21	3.36	2.01	0.67	2.01	100
Condensation	10.07	73.83	13.42	0.67	0.67	1.34	100
Sublimination	18.79	68.46	8.72	2.68	0.67	0.67	100
Deposition	12.08	59.06	20.13	3.36	2.01	3.36	100

From Table 7, the following information is obtained: (1) Question Number 1 (Melting) has 2.68% partial misconception and 1.34% of misconception; (2) Question Number 2 (Freezing) has 3.36% of partial misconception; (3) Question Number 3 (Vaporization) has 3.36% partial misconception and 2.01% misconception; (4) Question Number 4 (Condensation) has 13.42% partial misconception and 0.67% misconception; (5) Question Number 5 (Sublimination) has 8.72% partial misconception and 2.68% misconception; and (6) Question Number 6 (Deposition) has 20.13% partial misconception and 3.36% misconception. The findings of the five-tier multiple-choice diagnostic test

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demonstrate that the students had partial misconceptions (PM) on Question 5 and misconception (M) on Question 6. Students who were selected were numbered 4 and 80, the result are as follows.

Fig. 1. Question 5 (Student Number 4)

Fig. 2. Question 6 (Student Number 80)

Discussion

The five-tier multiple-choice diagnostic test about phase transition (FTMC-PT) can distinguish between prospective elementary school teachers who may understand the concepts, those who do not understand the concepts, those who have misconceptions, errors, do not understand and have misconceptions about some of the concepts. According to Table 7, the first question (melting) has a higher percentage of "(maybe) do not understand the concept." On the other hand, the sixth question (deposition) has the higher percentage of "(maybe) error." The fourth question (condensation) and the sixth question (deposition) have the percentage of "(maybe) have misconception" of 13.42% and 20.13% respectively. It should be noted that misconception and partial misconception are not the same. However, if the percentage is greater than 10% of the participants, it can be considered an error [9, 10, 11].

The misconceptions that occur in prospective elementary school teacher students include: in the event of a change in the shape of the particle, it does not experience movement; the motion of particles in the event of freezing, evaporating, and subliming is slower, while in the event of melting, condensing, depositing the motion of particles is faster; The shape and properties of the particles that make up matter are the same as those of the substances they are composed of. These results are in line with previous studies that solid particles are considered to be unable to move at all and the properties of the particles that make up the substance are the same as the substances they are composed of, and changes in form produce new substances [39]. The causes of misconceptions do not only come from educators, but can come from students who have inappropriate preconceptions, using wrong examples [40]. In addition, the status of misconceptions can occur because students have a high level of confidence in the wrong answers [41].

These findings can be used to analyze individual and group issues in learning and also can be utilized as a benchmark for learning improvement. This is in line with the previous study [27] stating that individual-level diagnosis will reflect individual strengths and weaknesses. Meanwhile, the group diagnosis will reflect the strengths and weaknesses of specific sub-concepts based on the test's score scale assessment. This finding is expected to assist educators in reviewing essential content in the learning phase transition concept. It will be easier to arrange a remedial teaching program by studying the needed materials and their achievements. Lecturers can repeat the questions (FTMC-PT) during the class to correct student's errors [41].

According to the findings, prospective elementary school teachers may experience misconceptions. This misconception should be addressed properly to make the learning process run smoothly and will not affect the understanding process of the next concept. This misconception among students motivates lecturers to conduct reflective learning. Categorizing the error types will be beneficial for lecturers to improve the learning process [42]. Students' misconceptions must be rectified so they will not take the misconception as the truth. This is one of the challenges in learning [26]. Misconceptions that are not rectified early will lead to new misconceptions. As a result, students will have a problem learning a concept [27]. It is said that misconceptions are a result of the lack of understanding of prerequisite material [30], [43].

As a result, understanding prerequisite concepts is essential for a student to learn a new concept because the prerequisite concept is crucial to understand the next concept [44]. Students who have misconceptions about a concept are more likely to have misconceptions about the next concept [29], [45]. Students must first comprehend the discontinuous nature of a matter and the dynamic nature of particles as a prerequisite to understand the phase transition concept. According to the previous study [46], students' understanding of particles has to be presented priorly before they learn the sub-microscopic level (structure, composition, and particle movement) in the phase transition class. Students with a thorough understanding of the discontinuous nature of a matter will have little trouble mastering phase transition at the submicroscopic level. Students with a good understanding of this subject are expected to apply what they have learned to other concepts. According to Treagust et al., students must be able to distinguish many forms of representation in science and use their prior knowledge to learn another representation [22]. For example, learning submicroscopic before learning macroscopic or learning symbolic before learning submicroscopic. It would be difficult for students to grasp the new concept without understanding the prerequisite concept [47-48]. To support this, the discontinuous nature of particles and their dynamic qualities as the prerequisite concept must be given and

presented in an entertaining way so that students can understand them before the learning phase transition.

In line with Kaltakci-Gurel et al., the results indicate that prospective teachers need to understand the phase transition concept [9]. In addition, the result of this study has an implication about classroom practice, including the development of a diagnostic instrument to identify students' misconceptions about phase transition that can help lecturers in designing and improving their lectures. For example, create a computer program based on diagnostic tests. Because it can help provide feedback to students immediately [49].

The five-tier test developed in this study is based on the representation of the material, so it may take a different form from that proposed by other authors. For example, five tiers are more focused on answer beliefs, reasons for answers, and the relationship between reasons and answer choices [50, 51, 52, 53]. The most important thing is how a diagnostic test can show certain parts of the material that have not been understood by students, and also provide information on how students think in answering a question.

V. Conclusions

The developed five-tier multiple-choice diagnostic test is valid and reliable in assessing prospective elementary school teachers' misconceptions about phase transition. It was also found that the developed test items can be used to analyze the problems about learning phase transition in science class. The misconceptions they experience include: in the event of a change in form, the particle does not experience movement; the motion of particles in the event of freezing, evaporating, and subliming is slower, while in the event of melting, condensing, depositing the motion of particles is faster; The shape and properties of the particles that make up matter are the same as those of the substances they are composed of. In addition, a high level of belief in the wrong answer also affects the status of misconceptions. The results suggest the need for further research to develop computer-generated test items and analyze them according to item response theory. It was found that further study is required to develop the test items and analyze them according to the item response theory.

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Results and Discussion	Please add miss-conception of face transition in the discussion more comprehensively
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We deeply thank ICMR 2021 Editor for reviewing our manuscript submitted to ICMR 2021 (ID A9) entitled "Five-tier multiple-choice diagnostic test development to identify prospective elementary school teachers' misconceptions about phase transitions". We were very pleased to read their comments and suggestions for improving our manuscript. We have addressed all comments and revised the manuscript accordingly.

Replies to the comments of reviewer:

Comment [1] General Comment: "The manuscript needs to be revised"
We accepted the comment. We have addressed all comments and revised the manuscript accordingly.

Comment [2] Title & Affiliation: "Ok"
We accepted the comment. Thank you.

Comment [3] Abstract: "The method in the abstract is too dominant"
We accepted the comment and some sentences have been corrected and partially removed, namely lines 7, 8, 9, 10, 11, 12 and 13.

Comment [4] Introduction: "Please add the last three years for reference"
We accepted the comment and add references [4], [5], [6], [7], [8]. [13], [14], [15] and [16].

Comment [5] Methods: "Method using past-tense, please reduce the theoritical consept"
We accepted the comments. The sentence in the method has been changed to past-tense. The theoretical concept section has been reduced, namely: paragraphs 2, 3, 4, and 5 have been reduced.

Comment [6] Results and Discussion: "Please add miss-conception of face transition in the discussion more comprehensively"
We accepted the comment and add explanations on line 17 to completion or paragraph 2 in the results and discussion section.

Comment [7] Conclusion: "Acknowledgement is not clear enough"
We accepted the comment and provide appropriate acknowledgment.

Comment [8] References: "Please add more newest references (2020-2021)"
We accepted the comment and add appropriate references, namely: [4], [5], [6], [7], [8], [13], [14], [15], [16], [29], [43], [48], [49], [50], [51], [52], and [53].

Comment [9] Layout: "Please follows the template"
We accepted the comment and revised the manuscript accordingly.

Comment [10] Language: "The quality of language should be increased"
We accepted the comment and revised the manuscript accordingly.

Comment [11] Decision: "Moderate revision"
We accepted the comment and revised the manuscript accordingly. We hope this revised manuscript will be accepted. Thank you.

Five-tier multiple-choice diagnostic test development to identify prospective elementary school teachers' misconceptions about phase transitions

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***Abstract*—This study aims to develop the five-tier multiple-choice diagnostic test to identify prospective elementary school teachers' misconceptions about phase transition using descriptive and verification methods. The subjects include 149 (116 female and 33 male) prospective elementary school teachers in one of the Elementary School Teacher Education Study Programs (ESTESP) in West Java. The stages of the study are as follows: (1) designing a five-tier test instrument to analyze students' misconceptions; (2) validation by experts; (3) instrument testing that was done on prospective teachers who have received phase transition materials; and (4) instrument testing that was done on prospective elementary school teachers who have not received phase transition teaching materials. The obtained data were analyzed descriptively using the percentage technique. In general, the results show that the developed test (FTMC-PT/*five-tier multiple choice-phase transitions*) is ideal for identifying students' conceptions about phase transition. However, further study to develop the test items and to analyze them accordingly as per the item response theory is required.**

Keywords—five-tier test, multiple-choice, misconception, prospective elementary school teachers, phase transition

I. INTRODUCTION

In the last decades, diagnostic tests have grown increasingly popular as a method for collecting data related to a misconception about science learning among students and teachers. As the initiator, Treagust developed a two-tier diagnostic method that explicitly identifies misconceptions and recommends adding a cause tier to determine the students' genuine misconceptions [1]. A two-tier test takes the shape of a system (response choice plus rationale) [2]. To achieve a three-tier, an additional layer of Certainty of Response Index (CRI) was proposed to supplement the limitations of the two-tier method. The three-tier test is formed as answer choice plus rationale plus CRI [3, 4, 5, 6, 7, 8]. Eventually, the three-tier test evolved into a four-tier test. According to Kaltakci-Gurel et al. [9], the four-tier test is a variation of Caleon and Subramaniam's three-tier test [10] that was modified into a four-tier structure [11] for learning mechanical waves concept. The four-tier test is a multi-tiered diagnostic test. Developed a four-tier diagnostic test (Answer Tier, Confidence Rating for Answer Tier, Reason Tier, and Confidence Rating for Reason Tier) [2].

Confidence Rating was added to the three-tier test and evolved into a four-tier test that increases the confidence level of an answer and the explanation for the answer will be more accurate. The four-tier test consists of four-level: multiple-choice questions to test knowledge, answer confidence level at the first level, answer rationale at the first level, and level of confidence (sure or unsure) of the answer's rationale at the third level [2], [9], [12, 13, 14, 15, 16].

The ability to recognize and manipulate concepts in various representations is an indicator of concept understanding [17] because understanding the concept will be closely related to consistency in solving a problem (question). Therefore, students that have grasped the concept will be able to solve the problem using the same principle, despite the differences in the context and representation [18].

There are three levels of material representation: macroscopic, submicroscopic, and symbolic [19]. Differences in knowledge at the submicroscopic level (verbal and visual) were identified in one study [20]. The distinction between verbal and visual aspects suggests that the submicroscopic level should be separated into two groups. It would be necessary given the fact that each level of representation is complimentary and connected, and each level of representation is critical for students to understand [21, 22, 23].

On the phase transition topic, Johnstone [19] suggests a submicroscopic division of verbal and visual, and the use of answer rationale tier, which is a five-tier test (diagnostic test). The five-tier diagnostic test consists of macroscopic level, verbal submicroscopic level, visual submicroscopic level, symbolic level, answer confidence level. It should be noted that because a diagnostic test is based on a conceptual approach [12], the response choices include some distractors resulting from students' preconceptions. These preconceptions are obtained from the literature and previous interview results (teachers and students) [24].

The development of a five-tier multiple-choice diagnostic test to assess prospective elementary school teachers' misconceptions about phase transition (FTMC-PT) is required to be studied. This study is necessary to solve learning issues and difficulties, improve student comprehension, and find a solution to eliminate student misconceptions. As a result, this study attempts to describe a diagnostic test for the phase transition topic. This test is for prospective elementary school teachers in their third semester assuming they had studied science throughout elementary and high school and had multiple science classes in the first semester. The goal of this study is to develop a valid and accurate five-tier multiple-choice diagnostic test to assess prospective elementary school teachers' misconceptions about phase transition. This study is expected to improve student's knowledge of educational materials as a learning reflection that may motivate them to take corrective measures and continue their studies.

II. THEORITICAL BACKGROUND

One of the causes of poor students' comprehension is misconception. According to scientific consensus [25-26], misconception is a deviation from the concept of an opinion. In this case, a diagnostic test is required to examine misconceptions [12], [27]. The development of a multiple-choice test to assess students' misconceptions can provide a significant contribution to the science teacher to incorporate research findings into their classroom [1]. These results can be used to determine whether a student has a complete understanding and to determine the correct and incorrect scores [28].

Experts continue to develop the multiple-choice test model by creating the Certainty of Response Index (CRI), which is an instrument that measures the confidence quality of a respondent's answer. CRI is a measure to determine how definite a student's response or answer to a question [2], [3], [9], [29]. If a student correctly answers a question and the CRI score is greater than 2.5, the student is considered to have a good grasp of the concept. However, if they answer the question incorrectly and the CRI is greater

than 2.5, the student has a misconception. Also, those who make a correct or incorrect answer with a CRI of less than 2.5 are categorized as do not understand the concept [30, 31, 32, 33, 34]. As shown in Table 1, Kadarohman, Nahadi, and Mira [26] developed diagnostic test criteria with two alternatives.

TABLE 1. Diagnostic test scoring criteria (Multiple Choice)

No.	Score	Explanation
1	2	If the answers and the rationales are correct or appropriate.
2	1	If the answer is correct, the rationale is wrong, or vice versa.
3	0	If the answer and rationale are wrong.

Based on the previous criteria, respondents with CRI < 2.5 with either correct or wrong answer is categorized as students who do not understand the concept. If those who "do not understand the concept" are given a score of "0," those who have "misconceptions" should be given a score below zero, such as "-1." For conceptual restructuring and minimizing misconceptions, 'more effort' is needed than the previous teaching [33]. Based on Table 1 and the CRI criteria above, the existing assessment criteria were modified, which is presented in Table 2.

TABLE 2. Assessment criteria for each item

No.	Answer choices for each Item	CRI Value	Score
1	Correct	> 2.5	2
2	Correct	< 2.5	1
3	Wrong	< 2.5	0
4	Wrong	> 2.5	-1

There are several levels of understanding that can be categorized: categorizing the three groups of understanding: understanding the concepts, misconceptions, and do not understand [26], [35], and categorizing of four groups of understanding: understand, partially understand (not sure with the answers given), misconceptions, and do not understand [30], [32], understand the concepts, do not understand the concepts, misconceptions, and errors [12], [36]. There are also two sections of the five-tier diagnostic test in this study. The first section is a concept-related question (stages 1-4), and the second section is the response certainty level using CRI for the concept-related question. Table 3 shows the categorization of the respondents' levels of understanding about the question items.

TABLE 3. Criteria level of understanding

No.	Answer options of the item	CRI Value	Category
1	All answers are correct	> 2.5	Understand
2	Wrong answer is found	< 2.5	Partial misunderstanding
3	Wrong answer is found	> 2.5	Partial misconception
4	All of the answers are wrong	> 2.5	Misconception
5	All answers are correct	< 2.5	Do not understand
6	All of the answers are wrong	< 2.5	Error

Based on Tables 2, 3, and the representations that have been described previously, a combination of five-tier multiple-choice diagnostic test answers related to phase transition can be developed as illustrated in Table 4.

TABLE 4. Five-tier test answer combination

No.	Answer choices of each stage					Score	Category
	I	II	III	IV	CRI Value		
1	C	C	C	C	> 2.5	8	UC
2	C	C	C	W	> 2.5	5	PUC
	C	C	W	C	> 2.5	5	PUC
	C	W	C	C	> 2.5	5	PUC
	W	C	C	C	> 2.5	5	PUC
	C	C	C	W	< 2.5	3	PUC
	C	C	W	C	< 2.5	3	PUC
	C	W	C	C	< 2.5	3	PUC
	W	C	C	C	< 2.5	3	PUC
	C	C	W	W	> 2.5	2	PUC
	C	W	W	C	> 2.5	2	PUC
	W	W	C	C	> 2.5	2	PUC
	C	W	C	W	> 2.5	2	PUC
	C	C	W	W	< 2.5	2	PUC
	C	W	W	T	< 2.5	2	PUC
	C	W	C	W	< 2.5	2	PUC
	W	W	C	C	< 2.5	2	PUC
	C	W	W	W	< 2.5	1	PUC
	W	W	W	C	< 2.5	1	PUC
	W	C	W	W	< 2.5	1	PUC
	W	W	C	W	< 2.5	1	PUC
3	C	W	W	W	> 2.5	-1	PM
	W	W	W	C	> 2.5	-1	PM
	W	C	W	W	> 2.5	-1	PM
	W	W	C	W	> 2.5	-1	PM
4	W	W	W	W	> 2.5	-4	M
5	C	C	C	C	< 2.5	4	DUC
6	W	W	W	W	< 2.5	0	E

Explanation: UC = Understand the concept; PUC = Partial Understanding of the concept; PM = Partial misconception of the concept; M = Misconception; DUC = Do not understand the concept; E = Error

III. METHOD

Development of a five-tier test for phase transition (FTMC-PT)

A five-tier multiple-choice test about phase transition (FTMC-PT) was developed in this study. This instrument had six items: question 1 was related to melting, question 2 was related to freezing, question 3 was related to vaporization, question 4 was related to condensation, question 5 was related to sublimation, and question 6 was related to deposition. The steps included designing a five-tier test instrument, validation process, instrument testing that was conducted to prospective teachers who had received phase transition materials, and instrument testing that was conducted to prospective elementary school teachers who had not received phase transition materials. The instrument validity test employed a construct validity test from experts using a validation sheet. After the expert validation step was done, the instrument test was conducted. As per the criteria, an item is valid if $r \geq 0.3$ [37] and could be considered reliable if the Cronbach's alpha result showed a coefficient of $\alpha \geq 0.7$ [38].

The subject of the Study

The subjects were 149 (116 female and 33 male) prospective elementary school teachers in one of the ESTESP in West Java.

Data Analysis

All 149 subjects' responses were inputted in Microsoft Excel, then sorted and graded as shown in Table 4. Next, the

data were descriptively evaluated using the percentage technique.

IV. RESULT AND DISCUSSION

The results of the test instrument validation by 3 validators the average is 87.50% (very valid) and the reliability of the test is indicated by the Cronbach Alpha value = 0.774 (reliable). Some of the research results are shown in the following table.

TABLE 5. Descriptive statistics of the test results

Element	Q.1	Q.2	Q.3	Q.4	Q.5	Q.6	score	Final score
Mean	4.84	5.03	3.50	2.99	3.48	2.36	22.20	46.2525
Median	5.00	5.00	3.00	2.00	2	2.00	21.00	43.7500
Mode	5	8	5	2	2	2	27	56.25
Std. deviation	2.712	2.715	2.525	2.623	3.004	3.027	11.505	23.96881
Minimum	-4	-1	-4	-4	-4	-4	-5	-10.42
Maximum	8	8	8	8	8	8	48	100
Sum	721	750	522	445	518	352	3308	6891.62

Table 5 above shows that the highest mean score is 5.03 with a standard deviation of 2.72 on Question 2 (Freezing), while the lowest average score is 2.36 with a standard deviation of 3.03 on Question 6 (Deposition). The highest possible score for all of the questions is 8. All questions have a minimum score of (-4) except Question 2 (Freezing), which has a minimum score of (-1).

TABLE 6. Correct answer percentage (Tier I - IV) and the confidence level of answers of the prospective elementary school teachers using a five-tier test

Tier		Q.1	Q.2	Q.3	Q.4	Q.5	Q.6
I		96.6	94.6	93.3	93.3	81.2	60.4
II		78.5	64.4	60.4	48.3	53.7	49
III		49.7	81.9	16.1	26.8	37.6	46.3
IV		76.5	63.8	77.9	63.8	72.5	52.3
V	0	1.34	0.67	2.01	1.34	0.67	2.68
	1	0.67	0.67	0	1.34	0.67	2.68
	2	12.8	12.8	15.4	17.4	16.1	22.1
	3	39.6	32.9	37.6	39.6	43	38.3
	4	28.9	32.9	29.5	27.5	26.2	22.8
	5	16.8	20.1	15.4	12.8	13.4	11.4

Table 6 shows that, for all questions, the percentage of tier III (visual submicroscopic level knowledge) is lower than the other tiers (I, II, and IV). In general, the confidence level of the answers with a value of more than 2.5 (CRI > 2.5) is dominant in all questions.

TABLE 7. The percentage of understanding of prospective elementary school teachers using five-tier test

Phase Transition	UC (%)	PUC (%)	PM (%)	M (%)	DUC (%)	E (%)	Total
Melting	31.54	59.06	2.68	1.34	4.70	0.67	100
Freezing	37.58	55.70	3.36	0.00	2.01	1.34	100
Vaporization	10.74	81.21	3.36	2.01	0.67	2.01	100
Condensation	10.07	73.83	13.42	0.67	0.67	1.34	100
Sublimination	18.79	68.46	8.72	2.68	0.67	0.67	100
Deposition	12.08	59.06	20.13	3.36	2.01	3.36	100

From Table 7, the following information is obtained: (1) Question Number 1 (Melting) has 2.68% partial misconception and 1.34% of misconception; (2) Question Number 2 (Freezing) has 3.36% of partial misconception; (3) Question Number 3 (Vaporization) has 3.36% partial misconception and 2.01% misconception; (4) Question Number 4 (Condensation) has 13.42% partial misconception and 0.67% misconception; (5) Question Number 5 (Sublimination) has 8.72% partial misconception and 2.68% misconception; and (6) Question Number 6 (Deposition) has 20.13% partial misconception and 3.36% misconception. The findings of the five-tier multiple-choice diagnostic test demonstrate that the students had partial misconceptions (PM) on Question 5 and misconception (M) on Question 6. Students who were selected were numbered 4 and 80, the result are as follows.

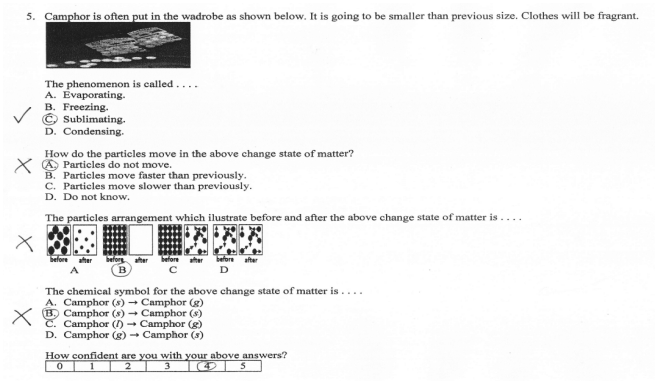

Fig. 1. Question 5 (Student Number 4)

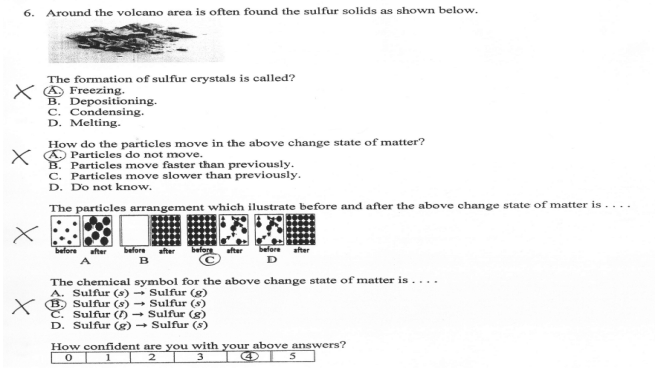

Fig. 2. Question 6 (Student Number 80)

Discussion

The five-tier multiple-choice diagnostic test about phase transition (FTMC-PT) can distinguish between prospective elementary school teachers who may understand the concepts, those who do not understand the concepts, those who have misconceptions, errors, do not understand and have misconceptions about some of the concepts. According to Table 7, the first question (melting) has a higher percentage of "(maybe) do not understand the concept." On the other hand, the sixth question (deposition) has the higher percentage of "(maybe) error." The fourth question (condensation) and the sixth question (deposition) have the percentage of "(maybe) have misconception" of 13.42% and 20.13% respectively. It should be noted that misconception and partial misconception are not the same. However, if the percentage is greater than 10% of the participants, it can be considered an error [9, 10, 11].

The misconceptions that occur in prospective elementary school teacher students include: in the event of a change in the shape of the particle, it does not experience movement;

the motion of particles in the event of freezing, evaporating, and subliming is slower, while in the event of melting, condensing, depositing the motion of particles is faster; The shape and properties of the particles that make up matter are the same as those of the substances they are composed of. These results are in line with previous studies that solid particles are considered to be unable to move at all and the properties of the particles that make up the substance are the same as the substances they are composed of, and changes in form produce new substances [39]. The causes of misconceptions do not only come from educators, but can come from students who have inappropriate preconceptions, using wrong examples [40]. In addition, the status of misconceptions can occur because students have a high level of confidence in the wrong answers [41].

These findings can be used to analyze individual and group issues in learning and also can be utilized as a benchmark for learning improvement. This is in line with the previous study [27] stating that individual-level diagnosis will reflect individual strengths and weaknesses. Meanwhile, the group diagnosis will reflect the strengths and weaknesses of specific sub-concepts based on the test's score scale assessment. This finding is expected to assist educators in reviewing essential content in the learning phase transition concept. It will be easier to arrange a remedial teaching program by studying the needed materials and their achievements. Lecturers can repeat the questions (FTMC-PT) during the class to correct student's errors [41].

According to the findings, prospective elementary school teachers may experience misconceptions. This misconception should be addressed properly to make the learning process run smoothly and will not affect the understanding process of the next concept. This misconception among students motivates lecturers to conduct reflective learning. Categorizing the error types will be beneficial for lecturers to improve the learning process [42]. Students' misconceptions must be rectified so they will not take the misconception as the truth. This is one of the challenges in learning [26]. Misconceptions that are not rectified early will lead to new misconceptions. As a result, students will have a problem learning a concept [27]. It is said that misconceptions are a result of the lack of understanding of prerequisite material [30], [43].

As a result, understanding prerequisite concepts is essential for a student to learn a new concept because the prerequisite concept is crucial to understand the next concept [44]. Students who have misconceptions about a concept are more likely to have misconceptions about the next concept [29], [45]. Students must first comprehend the discontinuous nature of a matter and the dynamic nature of particles as a prerequisite to understand the phase transition concept. According to the previous study [46], students' understanding of particles has to be presented priorly before they learn the sub-microscopic level (structure, composition, and particle movement) in the phase transition class. Students with a thorough understanding of the discontinuous nature of a matter will have little trouble mastering phase transition at the submicroscopic level. Students with a good understanding of this subject are expected to apply what they have learned to other concepts. According to Treagust et al., students must be able to distinguish many forms of representation in science and use their prior knowledge to learn another representation [22]. For example, learning submicroscopic before learning macroscopic or learning symbolic before learning submicroscopic. It would be difficult for students to grasp the new concept without understanding the prerequisite concept [47-48]. To support this, the discontinuous nature of particles and their dynamic qualities as the prerequisite concept must be given and presented in an entertaining way so that students can understand them before the learning phase transition.

In line with Kaltakci-Gurel et al., the results indicate that prospective teachers need to understand the phase transition concept [9]. In addition, the result of this study has an implication about classroom practice, including the development of a diagnostic instrument to identify students' misconceptions about phase transition that can help lecturers in designing and improving their lectures. For example, create a computer program based on diagnostic tests. Because it can help provide feedback to students immediately [49].

The five-tier test developed in this study is based on the representation of the material, so it may take a different form from that proposed by other authors. For example, five tiers are more focused on answer beliefs, reasons for answers, and the relationship between reasons and answer choices [50, 51, 52, 53]. The most important thing is how a diagnostic test can show certain parts of the material that have not been understood by students, and also provide information on how students think in answering a question.

V. CONCLUSIONS

The developed five-tier multiple-choice diagnostic test is valid and reliable in assessing prospective elementary school teachers' misconceptions about phase transition. It was also found that the developed test items can be used to analyze the problems about learning phase transition in science class. The misconceptions they experience include: in the event of a change in form, the particle does not experience movement; the motion of particles in the event of freezing, evaporating, and subliming is slower, while in the event of melting, condensing, depositing the motion of particles is faster; The shape and properties of the particles that make up matter are the same as those of the substances they are composed of. In addition, a high level of belief in the wrong answer also affects the status of misconceptions. The results suggest the need for further research to develop computer-generated test items and analyze them according to item response theory. It was found that further study is required to develop the test items and analyze them according to the item response theory.

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Five-tier multiple-choice diagnostic test development to identify prospective elementary school teachers' misconceptions about phase transitions

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***Abstract*—This study aims to develop the five-tier multiple-choice diagnostic test to identify prospective elementary school teachers' misconceptions about phase transition using descriptive and verification methods. The subjects include 149 (116 female and 33 male) prospective elementary school teachers in one of the Elementary School Teacher Education Study Programs (ESTESP) in West Java. The stages of the study are as follows: (1) designing a five-tier test instrument to analyze students' misconceptions; (2) validation by experts; (3) instrument testing that was done on prospective teachers who have received phase transition materials; and (4) instrument testing that was done on prospective elementary school teachers who have not received phase transition teaching materials. The obtained data were analyzed descriptively using the percentage technique. In general, the results show that the developed test (FTMC-PT/*five-tier multiple choice-phase transitions*) is ideal for identifying students' conceptions about phase transition. However, further study to develop the test items and to analyze them accordingly as per the item response theory is required.**

Keywords—five-tier test, multiple-choice, misconception, prospective elementary school teachers, phase transition

I. INTRODUCTION

In the last decades, diagnostic tests have grown increasingly popular as a method for collecting data related to a misconception about science learning among students and teachers. As the initiator, Treagust developed a two-tier diagnostic method that explicitly identifies misconceptions and recommends adding a cause tier to determine the students' genuine misconceptions [1]. A two-tier test takes the shape of a system (response choice plus rationale) [2]. To achieve a three-tier, an additional layer of Certainty of Response Index (CRI) was proposed to supplement the limitations of the two-tier method. The three-tier test is formed as answer choice plus rationale plus CRI [3, 4, 5, 6, 7, 8]. Eventually, the three-tier test evolved into a four-tier test. According to Kaltakci-Gurel et al. [9], the four-tier test is a variation of Caleon and Subramaniam's three-tier test [10] that was modified into a four-tier structure [11] for learning mechanical waves concept. The four-tier test is a multi-tiered diagnostic test. Developed a four-tier diagnostic test (Answer Tier, Confidence Rating for Answer Tier, Reason Tier, and Confidence Rating for Reason Tier) [2].

Confidence Rating was added to the three-tier test and evolved into a four-tier test that increases the confidence level of an answer and the explanation for the answer will be more accurate. The four-tier test consists of four-level: multiple-choice questions to test knowledge, answer confidence level at the first level, answer rationale at the first level, and level of confidence (sure or unsure) of the answer's rationale at the third level [2], [9], [12, 13, 14, 15, 16].

The ability to recognize and manipulate concepts in various representations is an indicator of concept understanding [17] because understanding the concept will be closely related to consistency in solving a problem (question). Therefore, students that have grasped the concept will be able to solve the problem using the same principle, despite the differences in the context and representation [18].

There are three levels of material representation: macroscopic, submicroscopic, and symbolic [19]. Differences in knowledge at the submicroscopic level (verbal and visual) were identified in one study [20]. The distinction between verbal and visual aspects suggests that the submicroscopic level should be separated into two groups. It would be necessary given the fact that each level of representation is complimentary and connected, and each level of representation is critical for students to understand [21, 22, 23].

On the phase transition topic, Johnstone [19] suggests a submicroscopic division of verbal and visual, and the use of answer rationale tier, which is a five-tier test (diagnostic test). The five-tier diagnostic test consists of macroscopic level, verbal submicroscopic level, visual submicroscopic level, symbolic level, answer confidence level. It should be noted that because a diagnostic test is based on a conceptual approach [12], the response choices include some distractors resulting from students' preconceptions. These preconceptions are obtained from the literature and previous interview results (teachers and students) [24].

The development of a five-tier multiple-choice diagnostic test to assess prospective elementary school teachers' misconceptions about phase transition (FTMC-PT) is required to be studied. This study is necessary to solve learning issues and difficulties, improve student comprehension, and find a solution to eliminate student misconceptions. However, FTMC-PT has not been found, and the use of representations in diagnostic tests on the prospective primary school teacher students' understanding regarding phase transition has not been investigated. Thus, this study attempts to describe a diagnostic test for the phase transition topic. This test is for prospective elementary school teachers in their third semester assuming they had studied science throughout elementary and high school and had multiple science classes in the first semester. The goal of this study is to develop a valid and accurate five-tier multiple-choice diagnostic test to assess prospective elementary school teachers' misconceptions about phase transition. This study is expected to improve the student's knowledge of educational materials as a learning reflection that may motivate them to take corrective measures and continue their studies.

II. THEORITICAL BACKGROUND

One of the causes of poor students' comprehension is misconception. According to scientific consensus [25-26], misconception is a deviation from the concept of an opinion. In this case, a diagnostic test is required to examine misconceptions [12], [27]. The development of a multiple-choice test to assess students' misconceptions can provide a significant contribution to the science teacher to incorporate research findings into their classroom [1]. These results can be used to determine whether a student has a complete understanding and to determine the correct and incorrect scores [28].

Experts continue to develop the multiple-choice test model by creating the Certainty of Response Index (CRI), which is an instrument that measures the confidence quality of a respondent's answer. CRI is a measure to determine how definite a student's response or answer to a question

[2], [3], [9], [29]. If a student correctly answers a question and the CRI score is greater than 2.5, the student is considered to have a good grasp of the concept. However, if they answer the question incorrectly and the CRI is greater than 2.5, the student has a misconception. Also, those who make a correct or incorrect answer with a CRI of less than 2.5 are categorized as do not understand the concept [30, 31, 32, 33, 34]. As shown in Table 1, Kadarohman, Nahadi, and Mira [26] developed diagnostic test criteria with two alternatives.

TABLE 1. Diagnostic test scoring criteria (Multiple Choice)

No.	Score	Explanation
1	2	If the answers and the rationales are correct or appropriate.
2	1	If the answer is correct, the rationale is wrong, or vice versa.
3	0	If the answer and rationale are wrong.

Based on the previous criteria, respondents with CRI < 2.5 with either correct or wrong answer is categorized as students who do not understand the concept. If those who "do not understand the concept" are given a score of "0," those who have "misconceptions" should be given a score below zero, such as "-1." For conceptual restructuring and minimizing misconceptions, 'more effort' is needed than the previous teaching [33]. Based on Table 1 and the CRI criteria above, the existing assessment criteria were modified, which is presented in Table 2.

TABLE 2**.** Assessment criteria for each item

No.	Answer choices for each Item	CRI Value	Score
1	Correct	> 2.5	2
2	Correct	< 2.5	1
3	Wrong	< 2.5	0
4	Wrong	> 2.5	-1

There are several levels of understanding that can be categorized: categorizing the three groups of understanding: understanding the concepts, misconceptions, and do not understand [26], [35], and categorizing of four groups of understanding: understand, partially understand (not sure with the answers given), misconceptions, and do not understand [30], [32], understand the concepts, do not understand the concepts, misconceptions, and errors [12], [36]. There are also two sections of the five-tier diagnostic test in this study. The first section is a concept-related question (stages 1-4), and the second section is the response certainty level using CRI for the concept-related question. Table 3 shows the categorization of the respondents' levels of understanding about the question items.

TABLE 3. Criteria level of understanding

No.	Answer options of the item	CRI Value	Category
1	All answers are correct	> 2.5	Understand
2	Wrong answer is found	< 2.5	Partial misunderstanding
3	Wrong answer is found	> 2.5	Partial misconception
4	All of the answers are wrong	> 2.5	Misconception
5	All answers are correct	< 2.5	Do not understand
6	All of the answers are wrong	< 2.5	Error

Based on Tables 2, 3, and the representations that have been described previously, a combination of five-tier multiple-choice diagnostic test answers related to phase transition can be developed as illustrated in Table 4.

TABLE 4. Five-tier test answer combination

No.	Answer choices of each stage					Score	Category
	I	II	III	IV	CRI Value		
1	C	C	C	C	> 2.5	8	UC
2	C	C	C	W	> 2.5	5	PUC
	C	C	W	C	> 2.5	5	PUC
	C	W	C	C	> 2.5	5	PUC
	W	C	C	C	> 2.5	5	PUC
	C	C	C	W	< 2.5	3	PUC
	C	C	W	C	< 2.5	3	PUC
	C	W	C	C	< 2.5	3	PUC
	W	C	C	C	< 2.5	3	PUC
	C	C	W	W	> 2.5	2	PUC
	C	W	W	C	> 2.5	2	PUC
	W	W	C	C	> 2.5	2	PUC
	C	W	C	W	> 2.5	2	PUC
	C	C	W	W	< 2.5	2	PUC
	C	W	W	T	< 2.5	2	PUC
	C	W	C	W	< 2.5	2	PUC
	W	W	C	C	< 2.5	2	PUC
	C	W	W	W	< 2.5	1	PUC
	W	W	W	C	< 2.5	1	PUC
	W	C	W	W	< 2.5	1	PUC
	W	W	C	W	< 2.5	1	PUC
3	C	W	W	W	> 2.5	-1	PM
	W	W	W	C	> 2.5	-1	PM
	W	C	W	W	> 2.5	-1	PM
	W	W	C	W	> 2.5	-1	PM
4	W	W	W	W	> 2.5	-4	M
5	C	C	C	C	< 2.5	4	DUC
6	W	W	W	W	< 2.5	0	E

Explanation: UC = Understand the concept; PUC = Partial Understanding of the concept; PM = Partial misconception of the concept; M = Misconception; DUC = Do not understand the concept; E = Error

III. METHOD

Development of a five-tier test for phase transition (FTMC-PT)

A five-tier multiple-choice test about phase transition (FTMC-PT) was developed in this study. This instrument had six items: question 1 was related to melting, question 2 was related to freezing, question 3 was related to vaporization, question 4 was related to condensation, question 5 was related to sublimation, and question 6 was related to deposition. The steps included designing a five-tier test instrument, validation process, instrument testing that was conducted to prospective teachers who had received phase transition materials, and instrument testing that was conducted to prospective elementary school teachers who had not received phase transition materials. The instrument validity test employed a construct validity test from experts using a validation sheet. After the expert validation step was done, the instrument test was conducted. As per the criteria, an item is valid if $r \geq 0.3$ [37] and could be considered reliable if the Cronbach's alpha result showed a coefficient of $\alpha \geq 0.7$ [38].

The subject of the Study

The subjects were 149 (116 female and 33 male) prospective elementary school teachers in one of the ESTESP in West Java.

Data Analysis

All 149 subjects' responses were inputted in Microsoft Excel, then sorted and graded as shown in Table 4. Next, the data were descriptively evaluated using the percentage technique.

IV. RESULTS AND DISCUSSION

The results of the test instrument validation by 3 validators the average is 87.50% (very valid) and the reliability of the test is indicated by the Cronbach Alpha value = 0.774 (reliable). Some of the research results are shown in the following table.

TABLE 5. Descriptive statistics of the test results

Element	Q.1	Q.2	Q.3	Q.4	Q.5	Q.6	score	Final score
Mean	4.84	5.03	3.50	2.99	3.48	2.36	22.20	46.2525
Median	5.00	5.00	3.00	2.00	2	2.00	21.00	43.7500
Mode	5	8	5	2	2	2	27	56.25
Std. deviation	2.712	2.715	2.525	2.623	3.004	3.027	11.505	23.96881
Minimum	-4	-1	-4	-4	-4	-4	-5	-10.42
Maximum	8	8	8	8	8	8	48	100
Sum	721	750	522	445	518	352	3308	6891.62

Table 5 above shows that the highest mean score is 5.03 with a standard deviation of 2.72 on Question 2 (Freezing), while the lowest average score is 2.36 with a standard deviation of 3.03 on Question 6 (Deposition). The highest possible score for all of the questions is 8. All questions have a minimum score of (-4) except Question 2 (Freezing), which has a minimum score of (-1).

TABLE 6. Correct answer percentage (Tier I - IV) and the confidence level of answers of the prospective elementary school teachers using a five-tier test

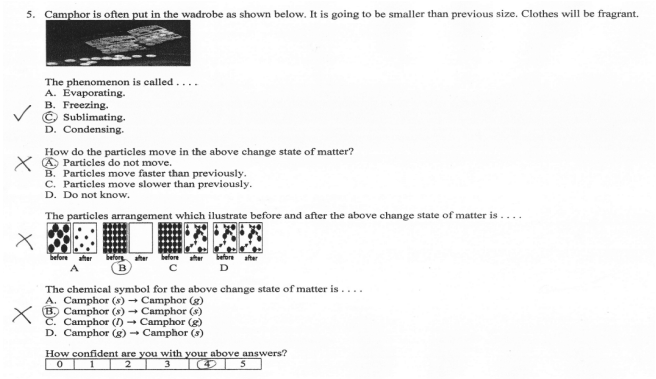
Tier		Q.1	Q.2	Q.3	Q.4	Q.5	Q.6
I		96.6	94.6	93.3	93.3	81.2	60.4
II		78.5	64.4	60.4	48.3	53.7	49
III		49.7	81.9	16.1	26.8	37.6	46.3
IV		76.5	63.8	77.9	63.8	72.5	52.3
V	0	1.34	0.67	2.01	1.34	0.67	2.68
	1	0.67	0.67	0	1.34	0.67	2.68
	2	12.8	12.8	15.4	17.4	16.1	22.1
	3	39.6	32.9	37.6	39.6	43	38.3
	4	28.9	32.9	29.5	27.5	26.2	22.8
	5	16.8	20.1	15.4	12.8	13.4	11.4

Table 6 shows that, for all questions, the percentage of tier III (visual submicroscopic level knowledge) is lower than the other tiers (I, II, and IV). In general, the confidence level of the answers with a value of more than 2.5 (CRI > 2.5) is dominant in all questions.

TABLE 7. The percentage of understanding of prospective elementary school teachers using five-tier test

Phase Transition	UC (%)	PUC (%)	PM (%)	M (%)	DUC (%)	E (%)	Total
Melting	31.54	59.06	2.68	1.34	4.70	0.67	100
Freezing	37.58	55.70	3.36	0.00	2.01	1.34	100
Vaporization	10.74	81.21	3.36	2.01	0.67	2.01	100
Condensation	10.07	73.83	13.42	0.67	0.67	1.34	100
Sublimination	18.79	68.46	8.72	2.68	0.67	0.67	100
Deposition	12.08	59.06	20.13	3.36	2.01	3.36	100

From Table 7, the following information is obtained: (1) Question Number 1 (Melting) has 2.68% partial misconception and 1.34% of misconception; (2) Question Number 2 (Freezing) has 3.36% of partial misconception; (3) Question Number 3 (Vaporization) has 3.36% partial misconception and 2.01% misconception; (4) Question Number 4 (Condensation) has 13.42% partial misconception and 0.67% misconception; (5) Question Number 5 (Sublimination) has 8.72% partial misconception and 2.68% misconception; and (6) Question Number 6 (Deposition) has 20.13% partial misconception and 3.36% misconception. The findings of the five-tier multiple-choice diagnostic test demonstrate that the students had partial misconceptions (PM) on Question 5 and misconception (M) on Question 6. Students who were selected were numbered 4 and 80, the result are as follows.


5. Camphor is often put in the wadrobe as shown below. It is going to be smaller than previous size. Clothes will be fragrant.

The phenomenon is called . . . .
A. Evaporating.
B. Freezing.
C. Sublimating.
D. Condensing.

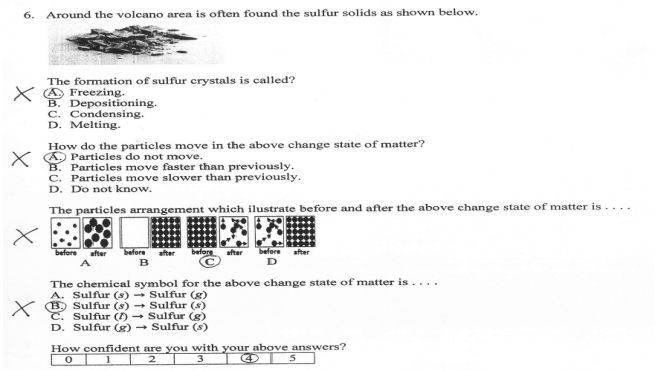
How do the particles move in the above change state of matter?
A. Particles do not move.
B. Particles move faster than previously.
C. Particles move slower than previously.
D. Do not know.

The particles arrangement which ilustrate before and after the above change state of matter is . . . .
A B C D

The chemical symbol for the above change state of matter is . . . .
A. Camphor (*s*) → Camphor (*g*)
B. Camphor (*s*) → Camphor (*s*)
C. Camphor (*l*) → Camphor (*g*)
D. Camphor (*g*) → Camphor (*s*)

How confident are you with your above answers?
0 1 2 3 4 5

Fig. 1. Question 5 (Student Number 4)


6. Around the volcano area is often found the sulfur solids as shown below.

The formation of sulfur crystals is called?
A. Freezing.
B. Depositioning.
C. Condensing.
D. Melting.

How do the particles move in the above change state of matter?
A. Particles do not move.
B. Particles move faster than previously.
C. Particles move slower than previously.
D. Do not know.

The particles arrangement which ilustrate before and after the above change state of matter is . . . .
A B C D

The chemical symbol for the above change state of matter is . . . .
A. Sulfur (*s*) → Sulfur (*g*)
B. Sulfur (*s*) → Sulfur (*s*)
C. Sulfur (*l*) → Sulfur (*g*)
D. Sulfur (*g*) → Sulfur (*s*)

How confident are you with your above answers?
0 1 2 3 4 5

Fig. 2. Question 6 (Student Number 80)

Discussion

The five-tier multiple-choice diagnostic test about phase transition (FTMC-PT) can distinguish between prospective elementary school teachers who may understand the concepts, those who do not understand the concepts, those who have misconceptions, errors, do not understand and have misconceptions about some of the concepts. According to Table 7, the first question (melting) has a higher percentage of "(maybe) do not understand the concept." On the other hand, the sixth question (deposition) has the higher percentage of "(maybe) error." The fourth question (condensation) and the sixth question (deposition) have the percentage of "(maybe) have misconception" of 13.42% and 20.13% respectively. It should be noted that misconception

and partial misconception are not the same. However, if the percentage is greater than 10% of the participants, it can be considered an error [9, 10, 11].

The misconceptions that occur in prospective elementary school teacher students include: in the event of a change in the shape of the particle, it does not experience movement; the motion of particles in the event of freezing, evaporating, and subliming is slower, while in the event of melting, condensing, depositing the motion of particles is faster; The shape and properties of the particles that make up matter are the same as those of the substances they are composed of. These results are in line with previous studies that solid particles are considered to be unable to move at all and the properties of the particles that make up the substance are the same as the substances they are composed of, and changes in form produce new substances [39]. The causes of misconceptions do not only come from educators, but can come from students who have inappropriate preconceptions, using wrong examples [40]. In addition, the status of misconceptions can occur because students have a high level of confidence in the wrong answers [41].

These findings can be used to analyze individual and group issues in learning and also can be utilized as a benchmark for learning improvement. This is in line with the previous study [27] stating that individual-level diagnosis will reflect individual strengths and weaknesses. Meanwhile, the group diagnosis will reflect the strengths and weaknesses of specific sub-concepts based on the test's score scale assessment. This finding is expected to assist educators in reviewing essential content in the learning phase transition concept. It will be easier to arrange a remedial teaching program by studying the needed materials and their achievements. Lecturers can repeat the questions (FTMC-PT) during the class to correct student's errors [41].

According to the findings, prospective elementary school teachers may experience misconceptions. This misconception should be addressed properly to make the learning process run smoothly and will not affect the understanding process of the next concept. This misconception among students motivates lecturers to conduct reflective learning. Categorizing the error types will be beneficial for lecturers to improve the learning process [42]. Students' misconceptions must be rectified so they will not take the misconception as the truth. This is one of the challenges in learning [26]. Misconceptions that are not rectified early will lead to new misconceptions. As a result, students will have a problem learning a concept [27]. It is said that misconceptions are a result of the lack of understanding of prerequisite material [30], [43].

As a result, understanding prerequisite concepts is essential for a student to learn a new concept because the prerequisite concept is crucial to understand the next concept [44]. Students who have misconceptions about a concept are more likely to have misconceptions about the next concept [29], [45]. Students must first comprehend the discontinuous nature of a matter and the dynamic nature of particles as a prerequisite to understand the phase transition concept. According to the previous study [46], students' understanding of particles has to be presented priorly before they learn the sub-microscopic level (structure, composition, and particle movement) in the phase transition class. Students with a thorough understanding of the discontinuous nature of a matter will have little trouble mastering phase transition at the submicroscopic level. Students with a good understanding of this subject are expected to apply what they have learned to other concepts. According to Treagust et al., students must be able to distinguish many forms of representation in science and use their prior knowledge to learn another representation [22]. For example, learning submicroscopic before learning macroscopic or learning symbolic before learning submicroscopic. It would be difficult for students to grasp the new concept without understanding the prerequisite concept [47-48]. To support this, the discontinuous nature of particles and their dynamic qualities as the prerequisite concept must be given and presented in an entertaining way so that students can understand them before the learning phase transition.

In line with Kaltakci-Gurel et al., the results indicate that prospective teachers need to understand the phase transition concept [9]. In addition, the result of this study has an implication about classroom practice, including the development of a diagnostic instrument to identify students' misconceptions about phase transition that can help lecturers in designing and improving their lectures. For example, create a computer program based on diagnostic tests. Because it can help provide feedback to students immediately [49].

The five-tier test developed in this study is based on the representation of the material, so it may take a different form from that proposed by other authors. For example, five tiers are more focused on answer beliefs, reasons for answers, and the relationship between reasons and answer choices [50, 51, 52, 53]. The most important thing is how a diagnostic test can show certain parts of the material that have not been understood by students, and also provide information on how students think in answering a question.

V. CONCLUSIONS

After conducting investigation on the use of representations in diagnostic tests on the prospective primary school teacher students' understanding regarding phase transition, it is found that the developed five-tier multiple-choice diagnostic test is valid and reliable in assessing the students' misconceptions about phase transition in science class. The result of the test could illustrate that the students have misconceptions in the following concepts: 1) in the event of a change in form, the particle does not experience movement; 2) the motion of particles in the event of freezing, evaporating, and subliming is slower, while in the event of melting, condensing, depositing the motion of particles is faster; 3) The shape and properties of the particles that make up matter are the same as those of the substances they are composed of. In addition, a high level of belief in the wrong answer also affects the status of misconceptions. The results of this study have several implications for classroom practice, including making computer programs based on diagnostic tests to facilitate the provision of feedback, and the need for training or debriefing for prospective teachers/teachers related to understanding phase transition. From this research, it is suggested that further research is needed to develop computer-based test items and analyze them according to

item response theory, and training for prospective elementary school teachers/teachers.

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Dear ICMR 2021 editor/Committee ICMR 2021,

We deeply thank ICMR 2021 Editor/Committee ICMR 2021 for reviewing our manuscript submitted to ICMR 2021 (ID A9_Reviewed_G1) entitled "Five-tier multiple-choice diagnostic test development to identify prospective elementary school teachers' misconceptions about phase transitions". We were very pleased to read their comments and suggestions for improving our manuscript. We have addressed all comments and revised the manuscript accordingly.

Replies to the comments of reviewer:

Commented [MFU1]: *I. INTRODUCTION: Please highlight the research gaps at the end of your introduction*
We accepted the comment and add explanations on paragraph 6 in introduction section.

Commented [MFU2]: *IV. RESULTS: RESULT + S*
We welcome comments and have added the letter s in the word results.

Commented [MFU3]: *V. CONCLUSIONS: Please highlight the research implications.*
We welcome this comment and have added the research implications on lines 17-26 to completion conclusion section.

We accepted the comment and revised the manuscript accordingly. We hope this revised manuscript will be accepted. Thank you.

Sincerely yours,
Author(s)
Anasufi Banawi

Advances in Social Science, Education and Humanities Research, volume 633
International Conference on Madrassah Reform 2021 (ICMR 2021)

Five-Tier Multiple-Choice Diagnostic Test Development: Empirical Evidences to Improve Students' Science Literacy

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ABSTRACT
This study aims to develop the five-tier multiple-choice diagnostic test to identify prospective elementary school teachers' misconceptions about phase transition using descriptive and verification methods. The subjects include 149 (116 female and 33 male students) prospective elementary school teachers in one of the Elementary School Teacher Education Study Programs (ESTESP) in West Java. The stages of the study are as follows: (1) designing a five-tier test instrument to analyze students' misconceptions; (2) validation by experts; (3) instrument testing that was done on prospective teachers who have received phase transition materials; and (4) instrument testing that was done on prospective elementary school teachers who have not received phase transition teaching materials. The obtained data were analyzed descriptively using the percentage technique. In general, the results show that the developed test (FTMC-PT/five-tier multiple choice-phase transitions) is ideal for identifying students' conceptions about phase transition. However, further study to develop the test items and to analyze them accordingly as per the item response theory is required.

Keywords: *Five-tier test, Multiple-choice, Misconception, Prospective elementary school teachers, Science Literacy.*

1. INTRODUCTION

In the last decades, diagnostic tests have grown increasingly popular as a method for collecting data related to a misconception about science learning among students and teachers. As the initiator, Treagust developed a two-tier diagnostic method that explicitly identifies misconceptions and recommends adding a cause tier to determine the students' genuine misconceptions [1]. A two-tier test takes the shape of a system (response choice plus rationale) [2]. To achieve a three-tier, an additional layer of Certainty of Response Index (CRI) was proposed to supplement the limitations of the two-tier method. The three-tier test is formed as answer choice plus rationale plus CRI [3–8]. Eventually, the three-tier test evolved into a four-tier test. According to Kaltakci-Gurel et al. [9], the four-tier test is a variation of Caleon and Subramaniam's three-tier test [10] that was modified into a four-tier structure [11] for learning mechanical waves concept. The four-tier test is a multi-tiered diagnostic test. Developed a four-tier diagnostic test (Answer Tier, Confidence Rating for Answer Tier, Reason Tier, and Confidence Rating for Reason Tier) [2].

Confidence Rating was added to the three-tier test and evolved into a four-tier test that increases the confidence level of an answer and the explanation for the answer will be more accurate. The four-tier test consists of four-level: multiple-choice questions to test knowledge, answer confidence level at the first level, answer rationale at the first level, and level of confidence (sure or unsure) of the answer's rationale at the third level [2], [9], [12–16].

The ability to recognize and manipulate concepts in various representations is an indicator of concept

understanding [17] because understanding the concept will be closely related to consistency in solving a problem (question). Therefore, students that have grasped the concept will be able to solve the problem using the same principle, despite the differences in the context and representation [18].

There are three levels of material representation: macroscopic, submicroscopic, and symbolic [19]. Differences in knowledge at the submicroscopic level (verbal and visual) were identified in one study [20]. The distinction between verbal and visual aspects suggests that the submicroscopic level should be separated into two groups. It would be necessary given the fact that each level of representation is complimentary and connected, and each level of representation is critical for students to understand [21–23].

On the phase transition topic, Johnstone [19] suggests a submicroscopic division of verbal and visual, and the use of answer rationale tier, which is a five-tier test (diagnostic test). The five-tier diagnostic test consists of macroscopic level, verbal submicroscopic level, visual submicroscopic level, symbolic level, answer confidence level. It should be noted that because a diagnostic test is based on a conceptual approach [12], the response choices include some distractors resulting from students' preconceptions. These preconceptions are obtained from the literature and previous interview results (teachers and students) [24].

The development of a five-tier multiple-choice diagnostic test to assess prospective elementary school teachers' misconceptions about phase transition (FTMC-PT) is required to be studied. This study is necessary to solve learning issues and difficulties, improve student comprehension, and find a solution to eliminate student misconceptions.

However, FTMC-PT has not been found, and the use of representations in diagnostic tests on the prospective primary school teacher students' understanding regarding phase transition has not been investigated. Thus, this study attempts to describe a diagnostic test for the phase transition topic. This test is for prospective elementary school teachers in their third semester assuming they had studied science throughout elementary and high school and had multiple science classes in the first semester. The goal of this study is to develop a valid and accurate five-tier multiple-choice diagnostic test to assess prospective elementary school teachers' misconceptions about phase transition. This study is expected to improve the student's knowledge of educational materials as a learning reflection that may motivate them to take corrective measures and continue their studies.

2. METHODS

One of the causes of poor students' comprehension is misconception. According to scientific consensus [25-26], misconception is a deviation from the concept of an opinion. In this case, a diagnostic test is required to examine misconceptions [12], [27]. The development of a multiple-choice test to assess students' misconceptions can provide a significant contribution to the science teacher to incorporate research findings into their classroom [1]. These results can be used to determine whether a student has a complete understanding and to determine the correct and incorrect scores [28].

Experts continue to develop the multiple-choice test model by creating the Certainty of Response Index (CRI), which is an instrument that measures the confidence quality of a respondent's answer. CRI is a measure to determine how definite a student's response or answer to a question [2], [3], [9], [29]. If a student correctly answers a question and the CRI score is greater than 2.5, the student is considered to have a good grasp of the concept. However, if they answer the question incorrectly and the CRI is greater than 2.5, the student has a misconception. Also, those who make a correct or incorrect answer with a CRI of less than 2.5 are categorized as do not understand the concept [30–34]. As shown in Table 1,

Table 1. Diagnostic test scoring criteria (Multiple Choice)

No	Score	Explanation
1	2	If the answers and the rationales are correct or appropriate.
2	1	If the answer is correct, the rationale is wrong, or vice versa.
3	0	If the answer and rationale are wrong.

Kadarohman, Nahadi, and Mira [26] developed diagnostic test criteria with two alternatives.

Based on the previous criteria, respondents with CRI < 2.5 with either correct or wrong answer is categorized as students who do not understand the concept. If those who "do not understand the concept" are given a score of "0," those who have "misconceptions" should be given a score below zero, such as "-1." For conceptual restructuring and minimizing misconceptions, 'more effort' is needed than the previous teaching [33]. Based on Table 1 and the CRI criteria above, the existing

Table 2. Assessment criteria for each item

No	Answer choices for each Item	CRI Value	Score
1	Correct	> 2.5	2
2	Correct	< 2.5	1
3	Wrong	< 2.5	0
4	Wrong	> 2.5	-1

Table 3. Criteria level of understanding

No	Answer options of the item	CRI Value	Score
1	All answers are correct	> 2.5	Understand
2	Wrong answer is found	< 2.5	Partial misunderstanding
3	Wrong answer is found	> 2.5	Partial misconception
4	All of the answers are wrong	> 2.5	Misconception
5	All answers are correct	< 2.5	Do not understand
6	All of the answers are wrong	< 2.5	Error

Table 4. Five-tier test answer combination

No	Answer choices of each stage					Score	Category
	I	II	III	IV	CRI Value		
1	C	C	C	C	> 2.5	8	UC
2	C	C	C	W	> 2.5	5	PUC
	C	C	W	C	> 2.5	5	PUC
	C	W	C	C	> 2.5	5	PUC
	W	C	C	C	> 2.5	5	PUC
	C	C	C	W	< 2.5	3	PUC
	C	C	W	C	< 2.5	3	PUC
	C	W	C	C	< 2.5	3	PUC
	W	C	C	C	< 2.5	3	PUC
	C	C	W	W	> 2.5	2	PUC
	C	W	W	C	> 2.5	2	PUC
	W	W	C	C	> 2.5	2	PUC
	C	W	C	W	> 2.5	2	PUC
	C	C	W	W	< 2.5	2	PUC
	C	W	W	T	< 2.5	2	PUC
	C	W	C	W	< 2.5	2	PUC
	W	W	C	C	< 2.5	2	PUC
	C	W	W	W	< 2.5	1	PUC
	W	W	W	C	< 2.5	1	PUC
	W	C	W	W	< 2.5	1	PUC
	W	W	C	W	< 2.5	1	PUC
3	C	W	W	W	> 2.5	-1	PM
	W	W	W	C	> 2.5	-1	PM
	W	C	W	W	> 2.5	-1	PM
	W	W	C	W	> 2.5	-1	PM
4	W	W	W	W	> 2.5	-4	M
5	C	C	C	C	< 2.5	4	DUC
6	W	W	W	W	< 2.5	0	E

assessment criteria were modified, which is presented in Table 2.

There are several levels of understanding that can be categorized: categorizing the three groups of understanding: understanding the concepts, misconceptions, and do not understand [26], [35], and categorizing of four groups of understanding: understand, partially understand (not sure with the answers given), misconceptions, and do not understand [30], [32], understand the concepts, do not understand the concepts, misconceptions, and errors [12], [36]. There are also two sections of the five-tier diagnostic test in this study. The first section is a concept-related question (stages 1-4), and the second section is the response certainty level using CRI for the concept-related question. Table 3 shows the categorization of the respondents' levels of understanding about the question items.

Based on Tables 2, 3, and the representations that have been described previously, a combination of five-tier multiple-choice diagnostic test answers related to phase transition can be developed as illustrated in Table 4.

2.1. Development of a five-tier test for phase transition (FTMC-PT)

A five-tier multiple-choice test about phase transition (FTMC-PT) was developed in this study. This instrument had six items: question 1 was related to melting, question 2 was related to freezing, question 3 was related to vaporization, question 4 was related to condensation, question 5 was related to sublimation, and question 6 was related to deposition. The steps included designing a five-tier test instrument, validation process, instrument testing that was conducted to prospective teachers who had received phase transition materials, and instrument testing that was conducted to prospective elementary school teachers who had not received phase transition materials. The instrument validity test employed a construct validity test from experts using a validation sheet. After the expert validation step was carried out, the instrument test was conducted. As per the criteria, an item is valid if $r \geq 0.3$ [37] and could be considered reliable if the Cronbach's alpha result showed a coefficient of $\alpha \geq 0.7$ [38].

2.2. The subjects of the Study

The subjects were 149 (116 female and 33 male students) prospective elementary school teachers in one of the ESTESP in West Java.

2.3. Data Analysis

All 149 subjects' responses were inputted in Microsoft Excel, then sorted and graded as shown in

Table 4. The data were descriptively evaluated using the percentage technique.

3. RESULTS AND DISCUSSIONS

The results of the test instrument validation by 3 validators the average is 87.50% (very valid) and the reliability of the test is indicated by the Cronbach Alpha value = 0.774 (reliable). Some of the research results are shown in the following table.

Table 5. Descriptive statistics of the test results

Elements	Q.1	Q.2	Q.3	Q.4	Q.5	Q.6	score	Final score
Mean	4.84	5.03	3.50	2.99	3.48	2.36	22.20	46.2525
Median	5.00	5.00	3.00	2.00	2	2.00	21.00	43.7500
Mode	5	8	5	2	2	2	27	56.25
Std. deviation	2.712	2.715	2.525	2.623	3.004	3.027	11.505	23.96881
Minimum	-4	-1	-4	-4	-4	-4	-5	-10.42
Maximum	8	8	8	8	8	8	48	100
Sum	721	750	522	445	518	352	3308	6891.62

Table 5 above shows that the highest mean score is 5.03 with a standard deviation of 2.72 on Question 2 (Freezing), while the lowest average score is 2.36 with a standard deviation of 3.03 on Question 6 (Deposition). The highest possible score for all of the questions is 8. All questions have a minimum score of (-4) except Question 2 (Freezing), which has a minimum score of (-1).

Table 6. Correct answer percentage (Tier I - IV) and the confidence level of answers of the prospective elementary school teachers using a five-tier test

Tier		Q.1	Q.2	Q.3	Q.4	Q.5	Q.6
I		96.6	94.6	93.3	93.3	81.2	60.4
II		78.5	64.4	60.4	48.3	53.7	49
III		49.7	81.9	16.1	26.8	37.6	46.3
IV		76.5	63.8	77.9	63.8	72.5	52.3
V	0	1.34	0.67	2.01	1.34	0.67	2.68
	1	0.67	0.67	0	1.34	0.67	2.68
	2	12.8	12.8	15.4	17.4	16.1	22.1
	3	39.6	32.9	37.6	39.6	43	38.3
	4	28.9	32.9	29.5	27.5	26.2	22.8
	5	16.8	20.1	15.4	12.8	13.4	11.4

Table 6 shows that, for all questions, the percentage of tier III (visual submicroscopic level knowledge) is lower than the other tiers (I, II, and IV). In general, the confidence level of the answers with a value of more than 2.5 (CRI > 2.5) is dominant in all questions.

From Table 7, the following information is obtained: (1) Question Number 1 (Melting) has 2.68% partial misconception and 1.34% of misconception; (2) Question Number 2 (Freezing) has 3.36% of partial misconception; (3) Question Number 3 (Vaporization) has 3.36% partial misconception and 2.01% misconception; (4) Question Number 4 (Condensation) has 13.42% partial misconception and 0.67% misconception; (5) Question Number 5 (Sublimination) has 8.72% partial misconception and 2.68% misconception; and (6) Question Number 6 (Deposition) has 20.13% partial misconception and 3.36% misconception. The findings of the five-tier multiple-choice diagnostic test demonstrate that the students had partial misconceptions (PM) on Question 5 and misconception (M) on Question 6. Students who were selected were numbered 4 and 80, the result are as follows.

Table 7. The percentage of understanding of prospective elementary school teachers using five-tier test

Phase Transition	UC	PUC	PM	M	DUC	E	Total
Melting	31.54	59.06	2.68	1.34	4.70	0.67	100
Freezing	37.58	55.70	3.36	0.00	2.01	1.34	100
Vaporization	10.74	81.21	3.36	2.01	0.67	2.01	100
Condensation	10.07	73.83	13.42	0.67	0.67	1.34	100
Sublimination	18.79	68.46	8.72	2.68	0.67	0.67	100
Deposition	12.08	59.06	20.13	3.36	2.01	3.36	100

The five-tier multiple-choice diagnostic test about phase transition (FTMC-PT) can distinguish between prospective elementary school teachers who may understand the concepts, those who do not understand the concepts, those who have misconceptions, errors, do not understand and have misconceptions about some of the concepts. According to Table 7, the first question (melting) has a higher percentage of "(maybe) do not understand the concept." On the other hand, the sixth question (deposition) has the higher percentage of "(maybe) error." The fourth question (condensation) and the sixth question (deposition) have the percentage of "(maybe) have misconception" of 13.42% and 20.13% respectively. It should be noted that misconception and partial misconception are not the same. However, if the percentage is greater than 10% of the participants, it can be considered an error [9–11].

The misconceptions that occur in prospective elementary school teacher students include: in the event of a change in the shape of the particle, it does not experience movement; the motion of particles in the event of freezing, evaporating, and subliming is slower, while in the event of melting, condensing, depositing the motion of particles is faster; The shape and properties of the particles that make up matter are the same as those of the substances they are composed of. These results are in line with previous studies that solid particles are considered to be unable to move at all and the properties of the particles that make up the substance are the same as the substances they are composed of, and changes in form produce new substances [39]. The causes of

misconceptions do not only come from educators, but can come from students who have inappropriate preconceptions, using wrong examples [40]. In addition, the status of misconceptions can occur because students have a high level of confidence in the wrong answers [41].

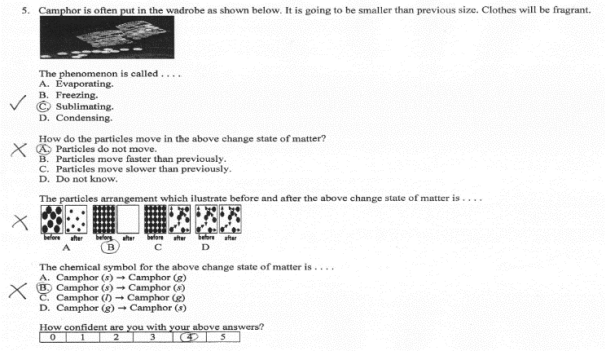

Figure 1 Question 5 (Student Number 4).

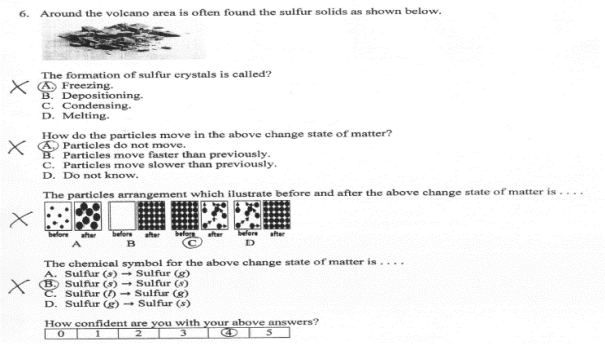

Figure 2 Question 6 (Student Number 80).

These findings can be used to analyze individual and group issues in learning and also can be utilized as a benchmark for learning improvement. This is in line with the previous study [27] stating that individual-level diagnosis will reflect individual strengths and weaknesses. Meanwhile, the group diagnosis will reflect the strengths and weaknesses of specific sub-concepts based on the test's score scale assessment. This finding is expected to assist educators in reviewing essential content in the learning phase transition concept. It will be easier to arrange a remedial teaching program by studying the needed materials and their achievements. Lecturers can repeat the questions (FTMC-PT) during the class to correct student's errors [41].

According to the findings, prospective elementary school teachers may experience misconceptions. This misconception should be addressed properly to make the learning process run smoothly and will not affect the understanding process of the next concept. This misconception among students motivates lecturers to conduct reflective learning. Categorizing the error types will be beneficial for lecturers to improve the learning process [42]. Students' misconceptions must be rectified so they will not take the misconception as the truth. This is one of the challenges in learning [26]. Misconceptions that are not rectified early will lead to new misconceptions. As a result, students will have a problem learning a concept [27]. It is said that misconceptions are a result of the lack of understanding of prerequisite material [30], [43].

As a result, understanding prerequisite concepts is essential for a student to learn a new concept because the prerequisite concept is crucial to understand the next concept [44]. Students who have misconceptions about a concept are more likely to have misconceptions about the next concept [29], [45]. Students must first comprehend the discontinuous nature of a matter and the dynamic nature of particles as a prerequisite to understand the phase transition concept. According to the previous study [46], students' understanding of particles has to be presented priorly before they learn the sub-microscopic level (structure, composition, and particle movement) in the phase transition class. Students with a thorough understanding of the discontinuous nature of a matter will have little trouble mastering phase transition at the submicroscopic level. Students with a good understanding of this subject are expected to apply what they have learned to other concepts. According to Treagust et al., students must be able to distinguish many forms of representation in science and use their prior knowledge to learn another representation [22]. For example, learning submicroscopic before learning macroscopic or learning symbolic before learning submicroscopic. It would be difficult for students to grasp the new concept without understanding the prerequisite concept [47], [48]. To support this, the discontinuous nature of particles and their dynamic qualities as the prerequisite concept must be given and presented in an entertaining way so that students can understand them before the learning phase transition.

In line with Kaltakci-Gurel et al., the results indicate that prospective teachers need to understand the phase transition concept [9]. In addition, the result of this study has an implication about classroom practice, including the development of a diagnostic instrument to identify students' misconceptions about phase transition that can help lecturers in designing and improving their lectures. For example, create a computer program based on diagnostic tests. Because it can help provide feedback to students immediately [49].

The five-tier test developed in this study is based on the representation of the material, so it may take a different form from that proposed by other authors. For example, five tiers are more focused on answer beliefs, reasons for answers, and the relationship between reasons and answer choices [50–53]. The most important thing is how a diagnostic test can show certain parts of the material that have not been understood by students, and

also provide information on how students think in answering a question.

4. CONCLUSION

After conducting investigation on the use of representations in diagnostic tests on the prospective primary school teacher students' understanding regarding phase transition, it is found that the developed five-tier multiple-choice diagnostic test is valid and reliable in assessing the students' misconceptions about phase transition in science class. The result of the test could illustrate that the students have misconceptions in the following concepts: 1) in the event of a change in form, the particle does not experience movement; 2) the motion of particles in the event of freezing, evaporating, and subliming is slower, while in the event of melting, condensing, depositing the motion of particles is faster; 3) The shape and properties of the particles that make up matter are the same as those of the substances they are composed of. In addition, a high level of belief in the wrong answer also affects the status of misconceptions. The results of this study have several implications for classroom practice, including making computer programs based on diagnostic tests to facilitate the provision of feedback, and the need for training or debriefing for prospective teachers/teachers related to understanding phase transition. From this research, it is suggested that further research is needed to develop computer-based test items and analyze them according to item response theory, and training for prospective elementary school teachers/teachers.

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