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Developing a Five-Tier Diagnostic Test to Identify Students' Misconceptions in Science: An Example of the Heat Transfer Concepts

Öğrencilerin Bilimsel Kavram Yanılgılarını Belirlemek İçin Beş Katmanlı Bir Tanı Testi Geliştirilmesi: Isı Transferi Kavramlarına Bir Örnek

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Abstract: The purpose of this article is to propose a new diagnostic test that can be used to diagnose students' deeper understanding of a concept and what they think about the concept. The instrument is a further development of the existing four-tier test by adding one more tier, drawing sub-microscopic representations. So, this new instrument is called a five-tier test. This instrument can diagnose students' conceptions in more details and a window to student thinking that can help teachers in diagnosing students' understanding. Concepts of heat transfer are chosen as the context for developing he instrument since they are considered as essential concepts in school science. The research involved 69 fifth-grade elementary school students from a school in Bandung-Indonesia. This study shows that the five-tier diagnostic test can be used to probe deeper understanding of students. It reveals that most elementary students know the concepts as at the macroscopic level but they had a lack of knowledge at the sub-microscopic level. This study offer new instrument for diagnosing students' understanding that can be useful for practical purpose as well as researchers.

Keywords: Diagnostic test, multiple-tier test, sub-microscopic representation drawing, misconceptions

Öz: Bu makalenin amacı, öğrencilerin bir kavram hakkında daha derin bir anlayış ve kavram hakkında ne düşündüklerini teşhis etmek için kullanılabilecek yeni bir tanı testi önermektir. Araç, mevcut bir dört aşamalı teste mikroskobik sunumlar adlı bir tane daha kademe ekleyerek daha da geliştirilmiştir. Bu yüzden, bu yeni enstrümana beş aşamalı test denir. Bu araç, öğrencilerin kavramlarını daha ayrıntılı olarak teşhis edebilir ve öğretmenlerin öğrencilerin anlamalarını teşhis etmelerine yardımcı olabilecek öğrenci düşüncesine yönelik bir pencere açabilir. Isı transferi kavramları, okul fen derslerinde temel kavramlar olarak kabul edildiklerinden, araç geliştirmede bağlam olarak seçilmiştir. Araştırma Bandung-Endonezya'daki bir okuldaki beşinci sınıf ilköğretim okulu öğrencisini içermektedir. Bu çalışma, beş aşamalı tanı testinin öğrencilerin daha derinlemesine anlaşılmasını sağlamak için kullanılabileceğini göstermektedir. İlköğretim öğrencilerinin çoğunun kavramları makroskobik düzeyde bildiklerini ancak mikroskobik düzeyde bilgi eksikliği olduğunu ortaya koymaktadır. Bu çalışma, araştırmacıların yanı sıra pratik amaç için yararlı olabilecek öğrencilerin anlayışını teşhis etmek için yeni bir araç sunmaktadır.

Anahtar Sözcükler: Tanı testi, çok katmanlı test, mikroskobik temsili çizim, kavram yanılgıları

INTRODUCTION

In order to find out the level of students' understanding and their conceptions, teachers or researchers usually administer various types of tests to determine students' learning outcomes. The common instrument, however, mainly assess the stage of students' understanding but they cannot provide sufficiently detailed information to determine students' scientific understanding

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(Kaltakci-Gurel, Eryilmaz, & McDermott, 2017; McDermott, 1991); hence, a diagnostic tool is required. Diagnostic tools have been widely developed and used by researchers, starting from interview, concept maps, open-ended or free response questionnaires, word association, drawings, multiple-choice tests, and multiple-tier tests such as two-tier, three-tier, and four-tier test (Kaltakci-Gurel et al., 2017; Kaltakci, 2012).

Multi-tier test is very useful for diagnosing students' conceptions of the concepts they have learned. This type of test not only provides information about the students' conception but also the reasons behind the answers. In addition, through this type of test, the teacher can find out the level of students' confidence to their understanding (Caleon & Subramaniam 2010a; Sreenivasulu & Subramaniam 2013). This article discusses the advantages and disadvantages of the existing diagnostic tests. It tries to reduce the shortcomings of the existing diagnostic tests by requesting students to make a sub-microscopic drawing of the phenomena.

Development of diagnostic multiple-tier tests

The multiple-choice test

The most recent diagnostic test used is the multiple-tier test, which is developed from the ordinary multiple-choice test. Although multiple-choice tests have the advantages such as strong validity (Downing, 2006); being easy to score, administer, and analyze; their coverage of a wide range of topics; and their flexibility to measure different levels of learning and cognitive skills (Caleon & Subramaniam, 2010; Kaltakci-Gurel, Eryilmaz, & McDermott, 2015), they also have disadvantages. For instance, students might be guessing the answers. The tests also cannot get more in-depth information about students' answers and their conceptual understanding; in addition, the tests have a limited list of answer choices, so students cannot give their own answers and there is the difficulty to write a good multiple-choice question (Chang et al., 2007). Because of these disadvantages, many researchers have developed multiple-choice tests with two, three, and four tiers to get the best tools to diagnose students' conceptions.

The two-tier test

The next diagnostic test is a two-tier multiple-choice. The difference from the ordinary multiple-choice lies in the addition of reasons for the answer to the main questions that students choose (Caleon & Subramaniam, 2010a; Tsai & Chou, 2002). Unlike a common multiple choice task with four options, only one of which is correct, where the probability of guessing the correct answer is 25%, in two-tier tasks, the probability of guessing is significantly reduced and equals approximately 6% (Milenković, Hrin, Segedinac, & Horvat, 2016). This type of test is possible to determine whether students have some misconceptions and to determine the level of conceptual understanding because the second tier test can evaluate the explanatory knowledge or the mental models of the students (Chang et al., 2007; Tsai & Chou, 2002). However, a two-tier test has a limitation. It cannot differentiate mistakes due to lack of knowledge from mistakes due to the existence of alternative conceptions. Also, it cannot distinguish correct responses due to adequate understanding from those due to guessing (Hasan, Bagayoko, & Kelley, 1999; Milenković et al., 2016). Thus, two-tier tests might overestimate or underestimate students' scientific conceptions (Chang et al., 2007).

The three-tier test

This kind of test is administered to determine whether the answers given to the first two-tiers are due to a misconception or a mistake due to a lack of knowledge (Kaltakci-Gurel et al., 2017). Researchers were encouraged to develop a more complex form of multiple-tier test which in addition to content and reason tiers contains an additional tier, the so-called "confidence" tier (Peşman & Eryılmaz, 2010; Sia, Treagust, & Chandrasegaran, 2012; Sreenivasulu & Subramaniam, 2013). In three-tier tests, the first tier is an ordinary multiple-choice test, the second tier is a multiple-choice test asking for reasoning, and the third tier asks students' confidence level for the given answer for the two previous tiers. In three-tier tests, the answers are correct if both choice and reason are correct with a high confidence. If students' answers are incorrect in both choice and reason and with a high confidence, the incorrect answers are considered as misconceptions.

These tests can more accurately elicit students' misconceptions since the tests can detect lack of knowledge percentages by means of the confidence tiers. This helps the users such that the obtained percentage of misconception is free from false positives, false negatives, and lack of knowledge (Kaltakci, 2012). The advantage of these tests lie in the ability to distinguish students' lack of knowledge from their misconceptions (Kaltakci-Gurel et al., 2015). Hence, they are considered to be able to assess students' misconceptions in a more valid and reliable way than the two-tier tests (Peşman & Eryılmaz, 2010). However, in these tests, the confidence level refers to the first and second tiers, so this might underestimate proportions of lack of knowledge and overestimate students' scores (Caleon & Subramaniam, 2010a; Kaltakci-Gurel et al., 2015) for this reason, one more tier is needed to improve the multiple-tier tests.

The four-tier test

The latest diagnostic test that has been developed is a four-tier test. The four-tier test is to complete the three-tier test. Syntactically, the *first* tier of this kind of test is an ordinary multiple-choice test with its distractors addressing specific misconceptions; the *second* tier of the test asks for the confidence of the answer in the first tier; the *third* tier of the test asks for the reasoning for the answer in the first tier; and the *fourth* tier of the test asks for the confidence of the answer in the third (reasoning) tier (Caleon & Subramaniam, 2010a; Kaltakci-Gurel et al., 2015; Kaltakci-Gurel et al., 2017). This four-tier test can also identify some misunderstandings in both the answers and the reasoning and provide information about the confidence level. By using such information, teachers may be better positioned to understand the nature of learners' misconceptions and consequently can support their students' progress in learning (Yang & Lin, 2015).

Even though the four-tier tests can identify misconceptions more clearly and support students' progress in learning, there is one part that has not been included in all multiple-tier tests, which is asking students to give their idea about a phenomenon or concept by drawing the explanations for the answer that has been chosen for the test. Herein, this article will discuss why we must add the drawing tier into diagnostic tests, delineate the ideas of a new diagnostic test, and explain what type of data we can get from this new diagnostic test.

Why do we need to add drawing to a diagnostic test?

Drawing test needs to be added into a diagnostic test because *first*, drawing is a powerful tool for thinking and communicating, regardless of the discipline; *second*, drawing is a process skill that is part of the practice of science, used in generating hypotheses, designing experiments, visualizing and interpreting data, and communicating results (Ainsworth, Prain, & Tytler, 2011; Quillin & Thomas, 2015; Schwarz et al., 2009) and *third*, drawing is a constructive and motivating activity as it combines hands-on and mind-on activities (Glynn & Muth, 2008).

Scientists do not only use words to explain their findings. They also use diagrams, graphics, videos, photos, and drawings or models to explain and tell their findings and excite public interest, like what Faraday and Maxwell do (Gooding, 2004). However, in science class, students are focused on interpreting the visuals of others. Although interpreting visualization and other information is very important to learn, science also requires students to develop representational skills. The use of drawing caters to individual learner differences, as a drawing is shaped by the learner's current or emerging ideas and knowledge of visual conventions (Ainsworth et al., 2011).

The drawing process combines two interactions: the external and representations of the mental model in the student. *First*, the brain naturally uses spatial information to encode other kinds of information, such as verbal and visual information, increasing the brain's capacity for memory and learning (Guida & Lavielle-Guida, 2014) both verbally and visually without regard to their learning style (Kirschner & van Merriënboer, 2013). *Second*, it considers verbal and visual information by using three congenial tasks: 1) selecting verbal and visual information from the material presented; 2) organizing verbal and visual information, and 3) integrating elements into the mental model. The external models require not only mental processes but also motor coordination to manipulate the image media to the desired image (Quillin & Thomas, 2015).

The process of drawing involves students/individuals in three processes taking place in their mind, namely: selecting, organizing, and integrating. Of these three processes then students will make a decision to make an image/model. In figure 1, there are small circles representing visual and/or verbal information and arrows that indicate how the process takes place until finally decisions are made.

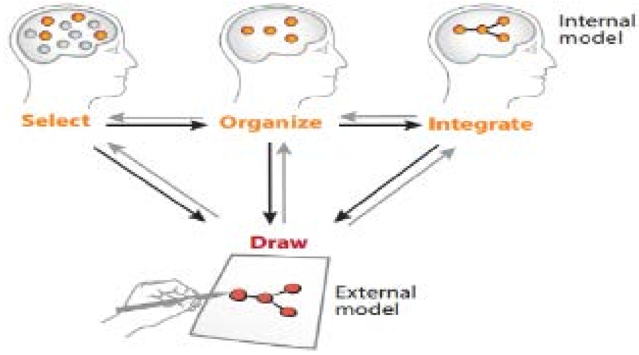


FIGURE 1. *The process of drawing* (Quillin & Thomas, 2015)

Drawing is a mechanism that can represent different expressions of a child through written or verbal media. It enables students to show their representational ways of thinking and their development (Einarsdottir, Dockett, & Perry, 2009; Haney, Russell, & Bebell, 2004). Drawing involves conceptual knowledge that serves as a way of documenting students' thinking, understanding, and change (Einarsdottir et al., 2009). Through drawing, students make their thinking explicit and specific, which leads to opportunities to exchange and clarify meanings between peers (Haney et al., 2004; Schwartz, 1995). The drawing they make will be a window to their thinking that can serve teachers in diagnostic, formative, and summative assessment (Ehrlén, 2009) because the drawing reflects an image of his/her mind (Pridmore & Bendelow, 1995).

More specifically, students' drawings in science can provide useful insights into common misconceptions or alternative conceptions (Bahar, Ozel, Prokop, & Usak, 2008; Dikmenli, 2010; Köse, 2008). As a technique for exploring ideas, drawing can provide holistic understanding and prevent students from feeling constrained by attempting to match their knowledge with that of the researcher (Dikmenli, 2010). Drawing can be a useful approach to probe understandings in children's learning. Drawing enables researchers to visualize and reveal the child's and teacher's qualities of understanding that can be hidden through other research procedures (Bahar et al., 2008).

The discussion indicates the importance of adding drawing into diagnostic tests. Since some students may have difficulties in representing their thinking, individual in-depth interviews were conducted to let students verbally explain their drawings or modify them. In this article, we present an assessment that can diagnose students' misconceptions with a comprehension test. The idea of this assessment is to complete the four-tier diagnostic tests with drawing that students create based on their explanations. This drawing is used to understand more deeply about what students understand and what is in the mind of the students. Drawing is also used as a simple research instrument for easy comparison (Reiss et al., 2002). Combination of drawing with written responses can also provide information for the teacher about what is in the child's mind (Prokop & Fancovicová, 2006).

The format of the five-tier test: An example of the heat transfer concepts

The five-tier developed in this study consist of 1) the main question; 2) confidence level; 3) reason for answers; 4) confidence level; and 5) a drawing/representation of the reasonable answers. An example of the test on heat transfer concepts is presented in Table 1 below (the complete test items is available in Appendix 1).

Table 1. *An example of the five-tier test format*

Question:
The main question about the conception
This morning is very cold. Mr. Anto wants to drink hot sweet tea to warm his body. And so, Mr. Anto makes hot tea by pouring boiled tea water into a glass, then putting sugar, and stirring it with a metal spoon as shown in the picture next to this column.

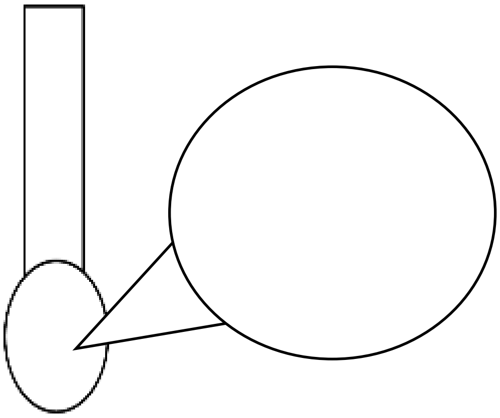
Answer Choice (tier 1):
What will happen to the tip of the spoon held by Mr. Anto, and why can it happen?
A. The tip of the spoon will be hot because the metal spoon is a conductor.
B. The tip of the spoon will be hot because the metal spoon is an insulator.
C. The tip of the spoon will not change (steady) because the metal spoon is an insulator.
D. (if you have your own answer, please write on here)…………………………………………………..

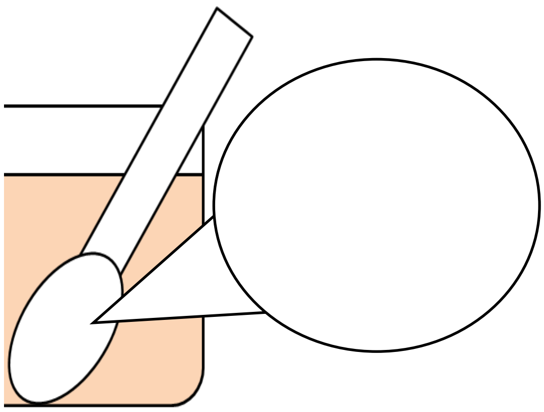
Confidence level in answer choice (tier 2)
Are you sure with your answers?
☐ Sure
☐ Not Sure

Reason (tier 3)
Why can it happen to a metal spoon?
A. The particles near to the heat source will enlarge and touching another particle around them and because of that the heat will be conducted.
B. The particles near to the heat source will be a transformation to another form and it makes the heat can be conduct.
C. The particles near to heat sources will spread throughout the spoon, so the spoon will be conducting the heat.
D. (if you have your own answer, please write on here)………………………………………….....................
....

Confidence level in reason answer (tier 4)
Are you sure with your answer?
☐ Sure
☐ Not Sure

Drawing (tier 5)
Draw how the metal spoon particles (in circle) look like before and after they are inserted into hot water.





Before Getting Inserted into Hot Water	**After Getting Inserted into Hot Water**

As in other multiple tests, this five-tier test also requires decisions on variations of answers given by students. The five-tier test has one additional tier, which is drawing the explanation of the last tier. Therefore, there are two possibilities of changing the explanation to the drawing: If an explanation matches the drawing, it is called "connected", and if the explanation does not match the drawing, it is called "not connected". The categorization for this five-tier test refers to that of a four-tier test. The main decision concerning the answer combination of students is presented in **Tabel 2** (see detail in appendix 2).

Table 2. Main combination answers and decision in five-tier test

No	Decision	Explanation
1.	SC (Scientific Conception)	Respondents provide correct answers at the macroscopic and sub-microscopic levels, confident in their answers, and the drawings are in accordance with scientific conceptions
2.	ASC (Almost Scientific Conception)	Respondents provide correct answers at the macroscopic and sub-microscopic levels, confident of their answers. However, the drawings are not fully in accordance with the scientific conception or are not closely connected to the explanation.
3.	LC (Lack of Confidence)	Respondents provide correct answers on the macroscopic and sub-microscopic level and the drawings are in accordance with scientific conceptions. However, they were not sure of the answers given.
4.	LK (Lack of Knowledge)	Respondents provide answers that partly true on macroscopic or sub-microscopic levels. They may either convince or not with the answers. The drawings are partly in accordance with scientific conception.
5.	MSC (Misconception)	The respondent provides either right or wrong answers at the macroscopic level and sub-microscopic level, but they fully confidence in the answers. The drawings, however, are not in accordance with the scientific conception.
6.	HNC (Have No Conception)	Respondents provide wrong answers at each level, Have no confidence with the answers, and they drawing do not meet the scientific conceptions

Adding drawings in the diagnostic test will help teachers or researchers get more information of what happens after students go through the learning process, and with this drawing tier teachers or researchers will discover students' conceptual understanding (Dikmenli, 2010). This skill needs to be developed in the learning process so that students can do more than just writing and speaking in the classroom. However, what is clear is the growing interest in drawing, as it reflects new understandings of science as a multimodal discursive practice, as well as mounting evidence for its value in supporting quality learning (Ainsworth et al., 2011). Drawing can also help to motivate students and make them more self-aware of their own learning (Quillin & Thomas, 2015). So, in teaching science teachers should integrate visual tools as representation in teaching and allow students to represent their understanding not only verbally but also visually (Sopandi, Kadarohman, Rosbiono, Latip, & Sukardi, 2018).

Various researchers used children's drawing to examine their ideas such as in concepts of water cycle (Dove, Everett, & Preece, 1999), the human body (Prokop & Fancovicová, 2006), the internal structure of animals (Prokop, Prokop, Tunnicliffe, & Diran, 2007), the heart's internal (Bahar et al., 2008), the cell division (Dikmenli, 2010), and the photosynthesis and respiration in plans (Köse, 2008) in order to provide empirical data. In this five-tier test, we combine the verbal and drawing conceptions into one instrument so with this instrument we can diagnose students' conceptions more clearly. Given all these reasons this study try to develop a five-tier diagnostic test that can be used to diagnose students' understanding of a concept and what they think about the concept.

METHOD

The participants of this study were 69 fifth grade students (28 boys and 41 girls) from a primary school in Bandung-Indonesia. The research employed a survey test method to determine students' understanding about the concept of conductivity and convection at a macroscopic level in the main question and at a sub-microscopic level in the reason question both on verbal and visual representations. The instrument of this research is called a five-tier test because it uses the multiple-tier choice (four-tier) and adds one more tier, a drawing tier. This instrument can diagnose students' conceptions in more details and can be the window to student thinking that can serve teachers in diagnostic, formative, and summative assessment. The format of the instrument in this research can be seen in Table 1 and the decision of the participants' answers can be seen detail in Appendix 2.

The instrument in this study consisted of two packages of questions on the concepts of conduction and convection. Each package consists of five questions starting from the question of the macroscopic, sub-microscopic level, level of confidence, and also the picture that draws by students. Responses are analyzed step by step following each tier. At For the first tier (macroscopic question), a respondent's response is checked whether it is correct or incorrect. Next, it is checked whether the respondent sure or not with the answer. For the third tier (sub-microscopic question), the respondent's response is checked it is correct or incorrect. Next, it is checked whether the respondent sure or not with the answer. Finally, for the fifth tier, the drawing produced by the respondent is compared to the answer of the tier-three question. A detailed analyses scheme is provided in appendix 2.

The test was validated in two steps. Firstly, it was validated by three experts in the field of science education at elementary school. The validators are two university lecturers with doctoral degree in science education and a teacher who has a doctoral degree in elementary education. An interrater reliability score of 0.82 on Kendall's tau was achieved amongst the experts shows that the instrument has a strong internal validity. Secondly, after having an agreement from the experts' judgment, this test was trialed to determine the empirical validity of this instrument. Correlation scores of 0.73 on Pearson Product Moment cores with $p < 0.05$ suggests that the test has good differentiate power. The reliability of this instrument tested with a Cronbach's Alpha was 0.652. Because this instrument includes a drawing test, the participants' drawings (visualization) were classified into six categories. The categories are adapted from Dikmenli's (2010) and Köse's (2008) ideas. An explanation of the category of student images can be seen in **Table 3**.

Table 3. The *categories of students' drawings*

No	Categories	Explanation
1.	*Scientific Drawing* (SD)	Respondents provide comprehensive visualizations that are in accordance with the scientific conceptions.
2.	*Partial Drawing* (PD)	The response provides a visualization that almost close to the scientific conception with minor deficiencies in the visualization.
3.	*Misconception Drawing* (MD)	Respondents provide less precise visualizations or different with scientific conception but they draw visualization at the sub-microscopic level.
4.	*Undefined Drawing* (UD)	Respondents provide visualizations that are not understandable, even though the visualization given is at the sub-microscopic level.
5.	*Non-Microscopic Drawing* (NMD)	Respondents provide visualization, but not at the sub-microscopic level.
6.	*No Drawing* (ND)	Respondents do not provide visualization at all or they just write their answers.

RESULTS

The results of this research to determine students' conceptions of the heat conduction using the five-tier test are shown in **Figure 2**.

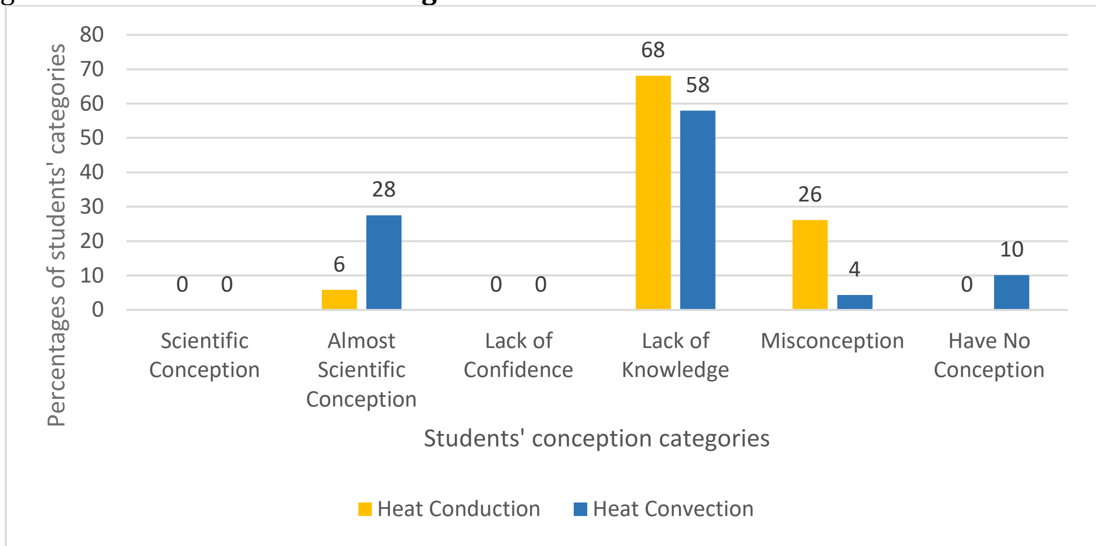


FIGURE 2. *The analysis of students' conception categories*

Figure 2 reveals that none of the students' in this research had a scientific conception of the heat conduction. Most of them lacked knowledge and had misconceptions, and only a few were in included in the category of "almost scientific conception". Students in this category could give correct answers from tier 1 to tier 4, but they could not make a scientific drawing based on the scientific conception. Based on this diagnostic test, most of them could give correct answers only to the main questions (macroscopic level) or the phenomena that can be seen, touched, and felt, but they could not give correct answers to the reasoning questions (sub-microscopic level). To see the research participants' answers in more detail, we can see **Figure 3.**

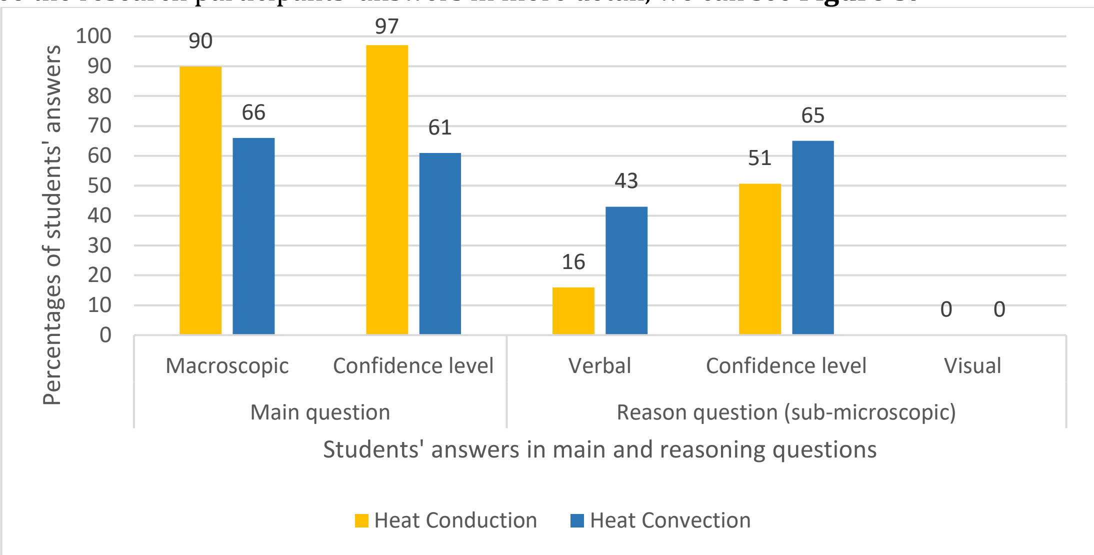


FIGURE 3. *The analysis of students' answers in main and reasoning question*

Figure 3 shows that students only knew at the macroscopic level, but they did not know why the phenomenon in question could happen. At the macroscopic level, even though it was not 100%, the level of confidence of students was very high. Nevertheless, at the sub-microscopic level only a few students could give a correct response and the level of confidence for this level was not as good as that of the macroscopic level and for the drawing tier; none of them could make a scientific drawing about the phenomenon in question. To further discover what the students thought about heat conduction and their understanding of why the metal spoon can conduct heat from one tip to another, we can see **Figure 4**.

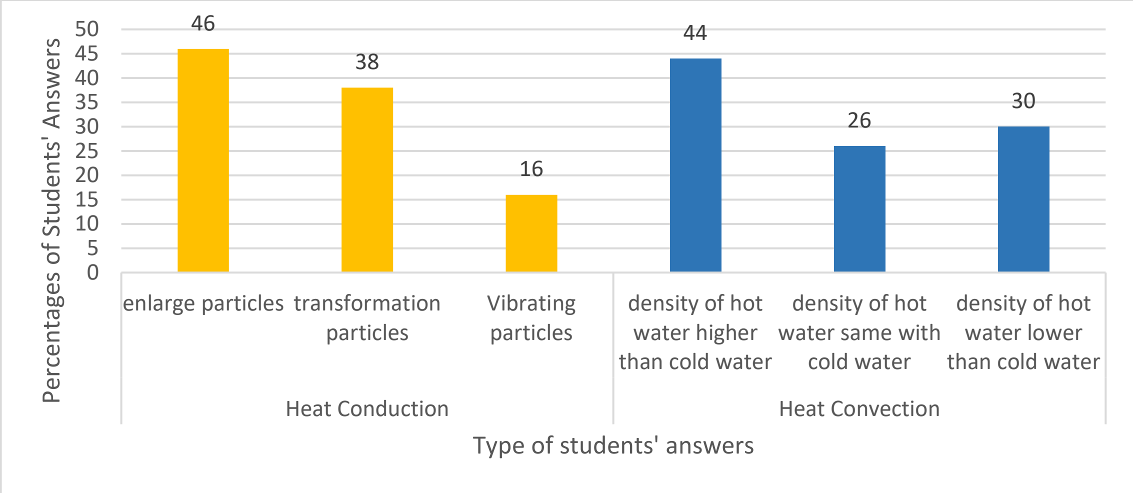


FIGURE 4. *Type of students' answers at sub-microscopic level*

Based on Figure 4, students seem to have an alternative conception about heat conduction. The students mostly thought that heat conduction could transpire because the particles enlarge or the particles transform into another form because of the heat emitted by the source. Only a few students gave correct answers (vibrating particles) about this phenomenon based on scientific conception. The last tier in this instrument is a drawing tier. Drawing tier is a useful tool to find about what students really think about the conception on their mind. The categories of students' drawings are shown in **Figure 5.**

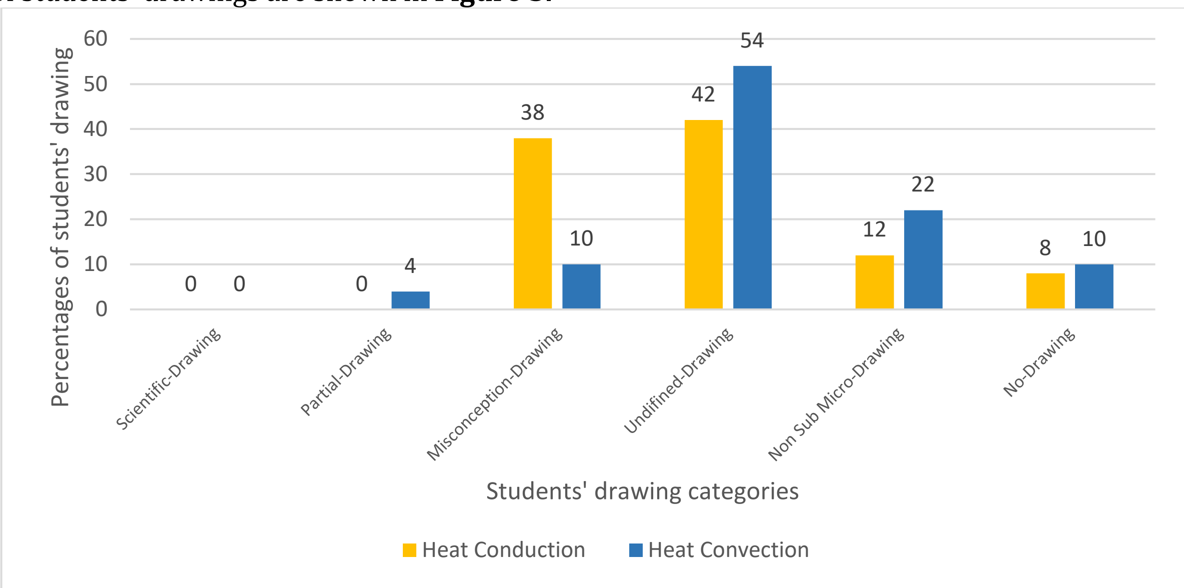
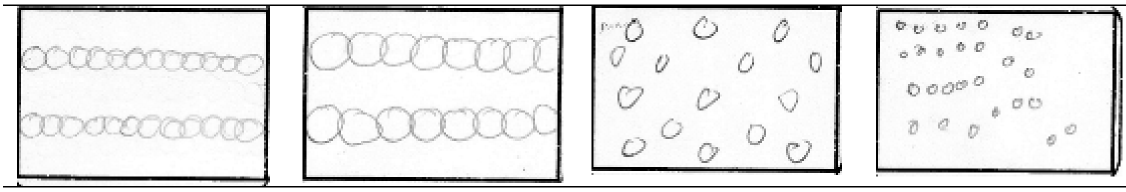


FIGURE 5. *The analysis of students' drawing based on categories*

Figure 5 shows us that none of the students' drawings was suitable for a scientific drawing. Most of the drawings fell into misconception and undefined drawing categories, and this most likely happened because students used their analogy at the macroscopic level to answer a phenomenon at a sub-microscopic level; meanwhile, to understand about heat conduction, they must know first about the concepts of particles (Çoruhlu, 2017) The example of the students' drawing at a conduction and convection concepts can be seen in **Figure 6 and 7**.

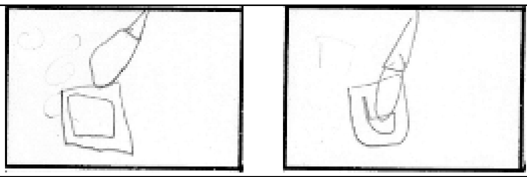
Misconception Drawing		Undefined Drawing	
Before inserted into a hot water	After inserted into a hot water	Before inserted into a hot water	After inserted into a hot water



Student number 14	Student number 17

Non-Microscopic Drawing

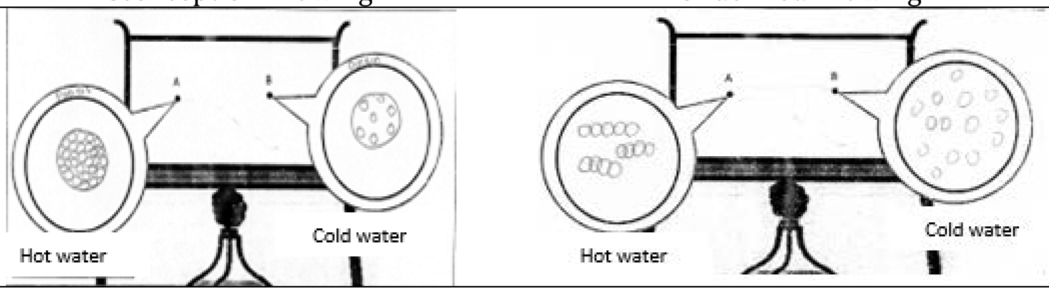
Before inserted into a hot water	After inserted into a hot water



Student number 56

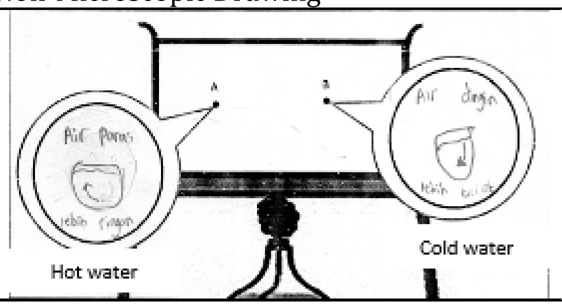
FIGURE 6. *Examples of students' drawing categories at conduction concept*

Misconception Drawing	Undefined Drawing



Student number 47	Student number 16

Non-Microscopic Drawing



Student number 45

FIGURE 7. *Examples of students' drawing categories at convection concept*

Figure 6 and 7 reveals that students were not familiar with questions at the sub-microscopic level, especially the visualization of the phenomena in question. From the examples at the conduction concept, it can be seen that student 14 thought that heat will make the particle enlarge. We can also get the point of what student 17 thought about the phenomena at the sub-microscopic level. Student 56 did not have any idea about the phenomenon at the sub-microscopic level, so she/he just drew what was on her/his mind. Similar to the concept of conduction, students also experienced misconception in drawing convention process. Student number 47, for example, gives an inverted drawing between the particles of hot water and cold water. None of the students' drawings can represent the vibrating particles when the heat conduction happens. Based on the analysis using the five-tier test, we can see that students' conception of heat conduction was not comprehensive. Almost all students only understood the concept at a macroscopic level and their understanding decreased at a sub-microscopic level, especially at the visualization of phenomena.

DISCUSSION and CONCLUSION

Based on the results of this research, we can see that the five-tier test can diagnose misconception in more detail and reveal what students' think about the concepts. With the drawing tier, we can also find out the reasons of students' misconceptions because the drawing is the reflection of what the students think in their mind. In addition, this five-tier test can be a new instrument for exploring students' ideas with the multiple-tier test and drawing test. This instrument can be a useful test because it combines many methods to gather information about students' conceptions (Kaltakci-Gurel et al., 2015; Schmidt, 1997).

The difference from other multiple-tier tests is that this test gives a space for students to figure out what they think about the concepts/phenomena in question. So, this test can cover students' conceptions more widely. By adding the drawing tier into the diagnostic test, we can know more about students' representations at sub-microscopic level, not only at the macroscopic and symbolic levels. This is important because in science there are three levels of representations, namely: 1) macroscopic, which describes the tangible and visible phenomena in everyday experiences; 2) sub-microscopic, which provides explanations at a particular level; and 3) symbolic that involves the use of science symbols, formula, and equations (Chandrasegaran, 2007; Johnstone, 1991; Nakhleh & Krajcik, 1994). And, the sub-microscopic level is the key to help students understand a phenomenon more easily because it can serve a bridge between the macroscopic and symbolic levels (Sopandi et al., 2018; Sopandi, Latip, & Sujana, 2017)

Drawing tier can also provide insight into a child's representational development (Anderson, Ellis, & Jones, 2014; Cherney, Seiwert, Dickey, & Flichtbeil, 2006) The drawing provides a reflection of what both students and teachers think about the content being presented and learned (Haney et al., 2004). By creating drawings or visualizations, students begin to move to higher-order thinking while working at a conceptual level. In this way, drawings assess science conceptual knowledge, observational skills, and the ability to reason (Anderson et al., 2014). The drawings emphasize ideas and concepts that are interesting to students and give insight into their understanding. The research results reveal that none of the students could give a correct drawing about heat conduction that is suitable for scientific conception. This phenomenon does not only happen to students, but the teacher also has the same problem in the drawing section (Anam, Widodo, & Sopandi, 2017). So, this research also gives evidence that the drawing tier is important to find about students' conception in more depth and it highlights the requirement for teachers to be able to facilitate this ability in science learning to make the learning more visual and easy to grasp.

The new categories of this test to show on whether students can give correct answers in the first, third, and the drawing tiers are connected to the reason tier (in three-tiered tests) that belongs to the lack of confidence category. So, with this decision, we should not underestimate students by assuming that they have a lack of knowledge because all the answers are correct. They just did not have the confidence and cannot do guessing because the drawing tier gives us information about their understanding and what they think. In addition, the three tier tests have no conception categories to indicate that students may not really understand the concept given, which explains why students have a lack of confidence in their answers. Even though this test requires a longer testing time, the test can give more complete diagnosis of students' misconceptions. Therefore, to make it easier for students draw in the concept test, the test has to provide a clear description of what kind of drawing is required for the test. From these discussions, it can be concluded that using the five-tier test we will gain more in-depth diagnosis of students' misunderstanding than with another multi-tier tests. **Table 4** represents the advantages and disadvantages of using this instrument.

Table 4. *The advantages and disadvantages of using five-tier tests instrument*

Point	The Advantages of Five-tier Test
The ability to diagnose students' misconceptions	Provides more explanations of how students understand and reveals their knowledge. Minimizes errors and lack of knowledge on the four-tier reinforced by the drawing or representation provided by the students.
The multiple-choice	Students can choose the answers provided on tests or give their own answers and make a drawing based on their explanation.
Decision Categories	Scientific Conceptions, Almost Scientific, Lack of Confidence, Lack of Knowledge, Misconception, and Have No Conception
Information obtain from the tests	This instrument can provide information on how students communicate their thinking about the concepts in their minds.
The outcomes of the tests	Useful for diagnostic purposes but also can provide information about students' representational outcomes.
Testing time	Requires a longer testing time and requires more concentration from students to create a drawing for the explanation given.

The five-tier test is developed by the researchers to diagnose students' misconceptions more clearly. Because this test combines the multiple-choice questions with drawing, students can decide their own answers if the multiple-choices do not give a satisfying answer through the drawing tier. With this test, we can get more data about students' conceptions and find out which part of the concepts students have already understood and not. The drawing tier can give us information not only about the reasoning skills of students but also about how they communicate their understanding through the drawings that they make. To get more information about the five-tier test to diagnose students' misconceptions, this instrument should be further tested in subsequent research.

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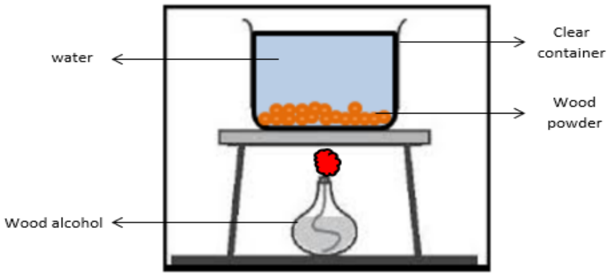
Appendix 1. Heat convection question

Question:
The main question about the conception

Fiyya is conducting an experiment by heating water in a clear container which there is contains wood powder. The aim of this experiment is to know how the movement of water represented by the movement of the wood powder. For more details, look at the picture below!



Answer Choice (tier 1):
What will happen to that experiment?

A. The closest water with the heat source will rise and the far ones will be above it.
B. The closest water with the heat source will rise and the far ones will replace their positions.
C. The near and far water from the heat source will stay in their position or no movement at all.
D. (if you have your own answer, please write on here)..

Confidence level in answer choice (tier 2)
Are you sure with your answers?

- ☐ Sure
- ☐ Not Sure

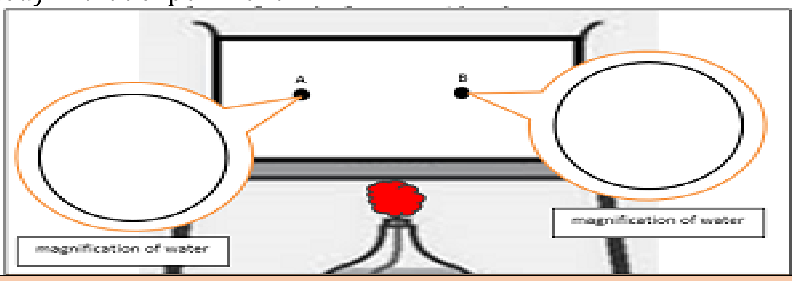
Reason (tier 3)
Why can it happen in that experiment?

A. The hotter water will have the same arrangement particles with the cooler one and there are no changes in position on both water conditions.
B. The hotter water will have more dense particles or become heavier than cooler one, therefore the particles of hot water will go down and cooler water will go up.
C. The hotter water will have more tenuous particles or become lighter than cooler one, the result hot water will go up and cooler water will go down.
D. (if you have your own answer, please write on here)..
....

Confidence level in reason answer (tier 4)
Are you sure with your answer?

- ☐ Sure
- ☐ Not Sure

Drawing (tier 5)
Based on your explanation, how do you draw the flow and particle of water at points A and B (in the circle provided) in that experiment.



Heated water phenomenon

Appendix 2. Combination answers and decision in five-tier test

No	1st tier	2nd tier	3rd tier	4th tier	5th tier	Decision
1.	Correct	Sure	Correct	Sure	Connected	**SC**
2.	Correct	Sure	Correct	Sure	Unconnected	**Almost SC**
3.	Correct	Sure	Correct	Not sure	Connected	**LC**
4.	Correct	Sure	Correct	Not Sure	Unconnected	**LK**
5.	Correct	Not sure	Correct	Sure	Connected	**LC**
6.	Correct	Not sure	Correct	Sure	Unconnected	**LK**
7.	Correct	Not sure	Correct	Not sure	Connected	**LC**
8.	Correct	Not sure	Correct	Not sure	Unconnected	**LK**
9.	Correct	Sure	Wrong	Sure	Connected	**MSC**
10.	Correct	Sure	Wrong	Sure	Unconnected	**LK**
11.	Correct	Sure	Wrong	Not sure	Connected	**LK**
12.	Correct	Sure	Wrong	Not sure	Unconnected	**LK**
13.	Correct	Not sure	Wrong	Sure	Connected	**LK**
14.	Correct	Not sure	Wrong	Sure	Unconnected	**LK**
15.	Correct	Not sure	Wrong	Not sure	Connected	**LK**
16.	Correct	Not sure	Wrong	Not sure	Unconnected	**LK**
17.	Wrong	Sure	Correct	Sure	Connected	**LK**
18.	Wrong	Sure	Correct	Sure	Unconnected	**LK**
19.	Wrong	Sure	Correct	Not sure	Connected	**LK**
20.	Wrong	Sure	Correct	Not sure	Unconnected	**LK**
21.	Wrong	Not sure	Correct	Sure	Connected	**LK**
22.	Wrong	Not sure	Correct	Sure	Unconnected	**LK**
23.	Wrong	Not sure	Correct	Not sure	Connected	**LK**
24.	Wrong	Not sure	Correct	Not sure	Unconnected	**LK**
25.	Wrong	Sure	Wrong	Sure	Connected	**MSC**
26.	Wrong	Sure	Wrong	Sure	Unconnected	**MSC**
27.	Wrong	Sure	Wrong	Not sure	Connected	**LK**
28.	Wrong	Sure	Wrong	Not sure	Unconnected	**LK**
29.	Wrong	Not sure	Wrong	Sure	Connected	**LK**
30.	Wrong	Not sure	Wrong	Sure	Unconnected	**LK**
31.	Wrong	Not sure	Wrong	Not sure	Connected	**LK**
32	Wrong	Not sure	Wrong	Not sure	Unconnected	**HNC**

SC: Scientific Conception; ASC: Almost Scientific Conception; LC: Lack of Confidence; LK: Lack of Knowledge; MSC: Misconception; HNC: Have No Conception.