Identification of misconceptions on heat and temperature among physics education students using four-tier diagnostic test

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Abstract. This study aims to identify misconceptions among physics education students in Yogyakarta on heat and temperature topic of physics education. This study uses descriptive study in terms of scanning model. The sample consist of 39 students majoring physics education in Yogyakarta. Data collection uses four-tier diagnostic test. This study not only intends to diagnose students’ misconceptions in depth analysis in five categories, but also diagnoses students’ conceptual understanding from each subaspect. The descriptive analysis findings of this study state that the four-tier diagnostic test instrument classifies students in five categories as the data analysis outcome about heat and temperature. They are scientific conceptual, lack of knowledge, misconception, false positive and false negative. The conceptual understanding of physics education students in Yogyakarta on heat and temperature topic varies greatly. Based on the results, the percentage of physics education students’ misconceptions in Yogyakarta varies on each subtopic misconception. The biggest misconception occurs in subtopic “thermal equilibrium only occurs if both systems contact directly” reached 61.5%. This shows that the student’s misconception is in high category and need special attention for educators to carry remediation out. Moreover, biggest misconception subtopic is needed more detailed explanations. In addition, this finding is expected to used as one of lecturers’ or teachers’ references to take consideration on the subtopic of heat and temperature which have many potential for misconception. Therefore, the teachers are able to implement the effective teaching strategy to overcome their students’ misconceptions on heat and temperature.

1. Introduction

Conceptual change has been a recent topic on science education researches since last 30 years ago [1]. These influence student’s natural science conceptualizatons [2-7]. The conceptual understanding is important in physics learning [8-9]. It has evolved the
Misconceptions are one of the dangerous situations in science teaching and learning. Moreover, it is due to student’s abstract nature concept which is a commonly faced in physics [16]. Physics misconceptions ensue both in high school students [17-23] and in physics education students as prospective physics teachers [24-30]. Physics education students who will later teach the basic concepts to their students, should have mastered the basic concepts. The low score in learning physics happen because they do not understand the basic concepts which implemented by the teacher and the lecturer. It shows that physics education students do not understand the concept of physics well. Students' incomprehension on the concept occurs due to students' misconceptions or failure of learning the conceptual understanding [31][32]. Moreover, It is caused of preconceptions or students understanding failure on the material which has not been taught yet.

Physics misconceptions occur in many topics. It consists of: heat and temperature [33-34]; dynamic fluid [17]; electrical circuit [27]; impulses and momentum [35]; friction [30]; static fluid [36]; power and energy. However, misconceptions of heat and temperature is in the high category. It reach 75% [33] until 84% [34]. Concerning on this topic, an instrument is needed to identify misconceptions [37]. There are a lot of instrument can used to identify misconceptions. It can used mind-mapping [38] or diagnostic tests [39-41]. Despite the diagnostic tests is an efficient tools to identify misconceptions, we also find that it can identify quickly than others. To add, there are many data on university students’ misconceptions regarding the diagnostic test instruments have been accumulated.

The Multiple Choice Test (MCT) can be administered into some forms. It is two tiers MCT [30][42-48]; three-tier MCT [34][49-51]; and four-tier MCT [41][52-55]. Although two tier and three tier MCT are only able to identify misconceptions [54], they still have limitations. The two tier MCT overestimates the misconception proportions. However, it is not able to determine the lack of knowledge [56]. Besides that, the three-tier MCT which is often used, have many limitations because of students’ confidence covert rating in the first and second tiers. To add, this circumstances generate in two centered problems. First, it underestimates the lack of knowledge sections. However, it is not able to determine whether the students’ confidence level on the first tier, second tier or both tiers. Second, it overestimates the physics students’ scores [56]. While four tier MCT have many advantages. It can: (a) explore deeper student conceptual understanding because there is a confidence level in the answers and reasons which can be chosen by respondents, (b) be more in diagnosing student misconceptions, (c) made reference material that requires emphasis on understanding more concepts, (d) being a reference to determine learning which can reduce student misconception [57]. In addition, it resists all the potency provided by Three-tier MCT and also estimate students’ misconceptions which both free of errors and lack of knowledge earnestly [58][60]. Thus, four tier MCT is deeply analysis on students’ misconception.
Misconception is influenced some factors. However, misconceptions’ causes break down in eight categories [34] [61]. It’s linked to the fact that a number of students’ concepts are coinciding in the first time. Moreover, they cannot remember the scientific concepts properly known as students’ preconceptions (P). In addition, it is influenced by students’ prior knowledge assimilating process which is not able to be incorporated or students’ intuition (I), wrong reasoning (R) or students incomplete reasons due to incomplete information and, humanistic thinking (HT) or monitoring all concept from the human perspective, and there’s student associative thinking (AT) too which thought that associate the concept to be the same to another. Despite of eight student’s misconceptions categorizations’ causes, in this these are identified for five factors.

In this study, it will examine the identification of physics education student misconceptions on heat and temperature topic using four tier MCT. This study is intended to be one of references for teachers, lecturers and other researchers to recognize which sub-topics are the biggest misconception points on heat and temperature.

2. Methodology of Research

The main purpose of this study identify physics education students’ misconceptions on heat and temperature topics. This study uses descriptive study in terms of scanning model. This due to get the general description of misconception on heat and temperature among university students in Yogyakarta. This methods is intended to describe existing phenomena, both natural phenomena and human engineering phenomena [62].

2.1. Population and Sampling

In this study, the population is all physics education students in Yogyakarta. While, the sample is 39 physics education students freshman of the physics education department in Yogyakarta. The purposive random sampling is used for the technique. The purposive sampling aims with sample students’ characteristic who have received deepening topic of heat and temperature.

2.2. Data Collection Tools

Four-tier MCT is a written test which have been used to investigate misconceptions among the physics education students. The first tier contains multiple choice questions with four answer choices. The second tier shows the respondent's confidence level with two chosen answer choices. The third tier contains open answers reasons. Fourth tier belief for the reasons chosen. While the respondents distribution analysis is classified in the answer decisions category. Four-tier MCT is an instrument which forms multiple choice in the first tier, second tier and fourth tier. While it forms open reasons choices in the third tier. The open reasons choice aims to make students more flexible to give reasons for answers. Besides that, it gives a space where students can write their reason for choosing that particular option [63].

Four tier MCT have been developed on five stages. They are analysis, planning, design, development, evaluation and revision. While developing four-tier MCT on heat and temperature, the literature scanning applied to identify some common misconceptions and identify the student's initial subtopic concept. Furthermore, it has been tested by a lecturer in physics education as an expert judgment for the content validity. There are 11 test items on heat and temperature used to probe students’ misconceptions. A pilot study has been investigate physics education students outside the sample due to inquire the four tier MCT the construct validity and reliability. The analysis result shows that the instrument has content validity of 0.794 which is in the high category. While it has construct validity of 0.654 which is in the high category. To add, the reliability is using the Spearman-Brown formula obtained r1 / 21/2 value of 0.887.
2.3 Data Analysis
Four tier MCT stated in the respondents distribution’s answer in many decisions level analysis [39]. It has five distribution categories of respondents. They are (a) scientific conceptual, (b) lack of knowledge, (c) misconception, (d) false positive and (e) false negative. The decisions of students' answers about understanding the concepts were analysed using Table 1 [56].

Table 1. Decision level answers for four-tier MCT

| 1st tier | 2nd tier | 3rd tier | 4th tier | Decision Level Answers |
|----------|----------|----------|----------|------------------------|
| Correct (C) | Sure (S) | Correct (C) | Sure (S) | Scientific Conception (SC) |
| Correct (C) | Sure (S) | Correct (C) | Not Sure (NS) | Lack of Knowledge (LK) |
| Correct (C) | Not Sure (NS) | Correct (C) | Sure (S) | Lack of Knowledge (LK) |
| Correct (C) | Not Sure (NS) | Correct (C) | Not Sure (NS) | Lack of Knowledge (LK) |
| Correct (C) | Sure (S) | Wrong (W) | Sure (S) | False Positive (FP) |
| Correct (C) | Sure (S) | Wrong (W) | Not Sure (NS) | Lack of Knowledge (LK) |
| Correct (C) | Not Sure (NS) | Wrong (W) | Sure (S) | Lack of Knowledge (LK) |
| Correct (C) | Not Sure (NS) | Wrong (W) | Not Sure (NS) | Lack of Knowledge (LK) |
| Wrong (W) | Sure (S) | Correct (C) | Sure (S) | False Negative (FN) |
| Wrong (W) | Sure (S) | Correct (C) | Not Sure (NS) | Lack of Knowledge (LK) |
| Wrong (W) | Not Sure (NS) | Correct (C) | Sure (S) | Lack of Knowledge (LK) |
| Wrong (W) | Not Sure (NS) | Correct (C) | Not Sure (NS) | Lack of Knowledge (LK) |
| Wrong (W) | Sure (S) | Wrong (W) | Sure (S) | Misconception (MSC) |
| Wrong (W) | Sure (S) | Wrong (W) | Not Sure (NS) | Lack of Knowledge (LK) |
| Wrong (W) | Not Sure (NS) | Wrong (W) | Sure (S) | Lack of Knowledge (LK) |
| Wrong (W) | Not Sure (NS) | Wrong (W) | Not Sure (NS) | Lack of Knowledge (LK) |

3. Result and Discussion
Four-tier MCT can reveal both the students’ level misconceptions from each categorization and the students’ level scientific conception from each subaspects [2-3][6-7]. The data analysis in table 1 indicate the frequencies and percentages of the 39 physics education students in accordance with questions along with their answer in Yogyakarta on the heat and temperature topic shows in Table 2. It shows conceptual understanding frequencies students’ number and percentage students’ number on heat and temperature of each problem indicators. Meanwhile, the description of student answers which is including misconceptions shows in table 3. It attempt describing students’ misconception of each problem indicators distinguishably. To add, the following 39 physics students conception percentage categories of heat and temperature clearly shown on Table 2.
The data analysis on table 2 shows that 40.3% students answered get misconception on the misconception for distinguishing the convection and radiation application in daily life subtopic. While 61.5% students answered get misconception on thermal equilibrium only occurs if both systems contact directly subtopic. In addition, 20.5% students answered get misconception on heat flow is in accordance with the convection flow subtopic and get 15.4% on the moving particles on conduction process subtopic. Moreover, 12.8% students answers get misconception on convection doesn’t occur in the air subtopic and get 8.3% on temperature and cold can flow subtopic.

Misconceptions which happen on physics education students because of their incorrect answer and reason with their wrong confidence on the concept of heat and temperature. Their conceptualization on heat and temperature might be used interchangeably. It have been examined a lot of researches many students are inclined in heat and temperature conceptualization interchangeably [33][64-65].

Table 2. Result recapitulation of conceptualization based on problem indicator

| Aspect    | Subaspect       | Problem Indicator                                                                 | SC | LK | MCS | FP | FN |
|-----------|-----------------|----------------------------------------------------------------------------------|----|----|-----|----|----|
| Interpreting | Interpretation | Thermal equilibrium only occurs if both systems contact directly                | 4  | 7  | .8  | .24| .5 |
| Exemplifying | Translation     | Temperature and cold can flow                                                   | 15 | 41 | .1  | .21| .62|
| Classifying | Illustration    | The moving particles on conduction process                                      | 11 | 28 | .2  | .22| .56|
| Summarising | Generalisation  | Convection does not occur in the air                                            | 5  | 12 | .8  | .29| .76|
| Inferring  | Exploration     | Heat flow is in accordance with convection flow                                | 7  | 17 | .9  | .23| .58|
| Analysis   |                 | The misconception for distinguishing the convection and radiation application in daily life | 5  | 11 | .7  | .16| .41|

FP: False Positive; FN: False Negative; MSC: Misconception; SC: Scientific Conception; LK: Lack of Knowledge

Misconceptions is tend to persist and resist to change. Misconceptions are someone different conceptions possessed and make contradictory on scientific conception. The stronger the misconceptions are, the bigger resist to scientific conceptual. Therefore, the sooner remediation of conceptual change embedded, the easier to extinguish the instruction addressed them [61]. The tabel 2 describe that students misconception percentage is in high category.

Figure 1 reveal the highest misconceptions’ causes is the intuition while obtaining the accordance of heat and convection flow; obtaining thermal equilibrium; obtaining the temperature and cold can flow and obtaining the moving particles on conduction process. However, misconceptions’ causes on reasoning while obtaining the air convection. It shows that displacement conceptual understanding on heat and temperature material is
caused by faulty intuition so students answer the question spontaneously. It is reinforced by a strong student institution reasonably so it is arduous to fix. Therefore, scientific children's early intuitions on natural phenomenon should build sooner due to be used as a foundation to build scientific concept. Indeed, building ground scientific conceptions is important in science teaching and learning [66].

Table 3. Misconceptions on heat and temperature

| No | Problem Indicator                                                                 | Student Answers Including Misconceptions                                                                 |
|----|-----------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------|
| 1  | Thermal equilibrium only occurs if both systems contact directly                   | “The copper glass thermal equilibrium faster than plastic glass because the thermal conductivity of copper cups is higher than plastic”
|    |                                                                                  | “Iron glass and plastic glass will have a different temperature although they have been on the same system for several days due to the higher iron conductivity influence”
|    |                                                                                  | ”After a few days at the same temperature and room, a chair made of iron will have a lower temperature than a plastic chair because it is cooler than plastic”
| 2  | Temperature and cold can flow                                                     | “In the morning, the body will feel cold due to convection and conduction events. This happens because heat moves from the body to the air by conduction and convection”
|    |                                                                                  | “When holding an iced glass, the hands will feel in normal temperature due to the grounds of the moving ice heat to the hands and the moving hands heat to the ice”
| 3  | The moving particles on conduction process                                        | “Colloidal media are easier to deliver heat than solids because they are the best conduction medium”
|    |                                                                                  | “If the iron pipe tip is heated, surrounding pipe will be hot son due to convection events because of the heated molecules move to the cold”
| 4  | Convection does not occur in the air                                              | “Convection is easiest to occur in liquid and colloidal medium because the particles move easily that media”
| 5  | Heat flow is in accordance with convection flow                                   | “The temperature around the bonfire is just as hot because the rate of conduction and the rate of radiation are the same”
| 6  | The misconception for distinguishing the convection and radiation application in daily life | “The heat of the bonfire is irradiated without going through the medium”
|    |                                                                                  | “The hair dryer works by convection of the heat element is irradiated the air surrounding first”
Figure 1. Misconceptions Factor of Physics Education Students

1: Preconceptions; I: Intuition; R: Wrong Reasoning; HT: Humanistic Thinking; AT: Associative Thinking
4. Conclusion
To summarize, the four tier MCT instrument can measure the concept understanding of prospective physics teacher students’ in varies category of conceptions: Scientific Understanding (SC), Lack of Knowledge (LK), Misconceptions (MCS) and False Positive (FP) and False Negative (FN). While the students’ misconceptions causes break down in five categorize. They are preconceptions (P); Intuition (I); Wrong Reasoning (W); Humanistic Thinking (HT); Associative Thinking (AT). To add, it can category students’ conceptual understanding from each subspect. The biggest misconception occurs in "thermal equilibrium only occurs if both systems contact directly" interprates that students lack on interpretating the condition on thermal equilibrum. In addition, the largest frequencys of students’ conceptual understanding in many level categories is various as follows: “temperature and cold can flow” on scintific conception, “convection does not occur in the air” on lack of knowledge, “thermal equilibrium only occurs if both systems contact directly” both on misconception and false positive,” the misconception for distinguishing the convection and radiation application in daily life” on false negative.

In the light of the findings, physics education student conceptual understanding on heat and temperature varies greatly on each indicators problem. The biggest misconception occurs in sub of "thermal equilibrium only occurs if both systems contact directly” of 61.5% due to varied causes. Meanwhile, this value interpretes that students’ lack on interpret the condition on thermal equilibrum. Moreover, it causes displacement conceptual understanding by students’ faulty intuition. So that, they answer the question spontaneously. However, the student's misconception need special attention for educators to provide more detailed explanations on some subtopic and attempt remediation of heat and temperature. Indeed, physics education student as physics teacher candidates should increase the interest level and eradicate the negative attitudes towards heat and temperature learning process. While the lecturer should find out the appropriate learning model in many designations of concept, laboratory and educational technology might be used so the more interesting and attractive course will create. Despite of remediation, diagnosing misconception may be enggaged to investigate students’ misconceptions sooner while starting a new topic. The sooner lecturer’s consideration of misconception number while starting the course, the sooner scientific concept reconstitutions reemerges.

References
[1] Nadelson L S, Heddy B C, Suzanne J, Taasoobshirazi G and Johnson M 2018 Conceptual change in science teaching and learning: Introducing the dynamic model of conceptual change International Journal F Educational Pshycology 7 151–95 https://doi.org/10.17583/ijep.2018.3349
[2] Bevir M 2003 Notes toward an analysis of conceptual change Social Epistemology 17 55-63
[3] Georgiades P 2000 Beyond conceptual change learning in science education: Focusing on transfer, durability and metacognition Educational Research 42 119-39
[4] Hayes B, Foster K and Gadd N 2003 Prior knowledge and subtyping effects in children’s category learning Cognition 88 171-99
[5] Kang S, Scharmann L C and Noh T 2004 Re-examining the role of cognitive conflict in science concept learning Research in Science Education 34 71-96
[6] Macbeth D 2000 On an actual apparatus for conceptual change Science Education 84 228-64
[7] Venville G 2004 Young children learning about living things: a case study of conceptual change from ontological and social perspectives Journal of Research
in Science Teaching 41 449-80

[8] Huda C, Sulisworo D and Toifur M 2017 Analisis Buku Ajar Termodinamika dengan Konsep Technological Pedagogical and Content Knowledge (TPACK) untuk Penguatan Kompetensi Belajar Mahasiswa Jurnal Penelitian Pembelajaran Fisika 8 1–7 https://doi.org/10.26877/jp2f.v8i1.1330

[9] Mardiyah A and Ariaji R 2017 Dan Aktivitas Mahasiswa Melalui 1 15–20

[10] Stathopoulou C and Vosniadou S 2007 Exploring the relationship between physics-related epistemological beliefs and physics understanding Contemp. Educ. Psychol. 32 255–281 https://doi.org/10.1016/j.cedpsych.2005.12.002

[11] Pratama N S and Istiyono E 2015 Studi pelaksanaan pembelajaran Fisika berbasis Higher Order Thinking (HOTS) pada kelas X di SMA Negeri Kota Yogyakarta PROSIDING : Seminar Nasional Fisika Dan Pendidikan Fisika 6 104–12

[12] Sma M D I (n.d.). 1 , 2 , 3, 1–12.

[13] Pesman H and Eryilmaz A 2009 J. Educ. Res. 10 208

[14] Snir J, Smith C L and Raz G 2003 Linking phenomena with competing underlying models: A software tool for introducing students to the particulate model of matter Science Education 87 6 794–830

[15] Aydoan S 2012 Establishment for misconceptions that sciences teacher candidates have about geometric optics The Online Journal of New Horizons in Education 2 7-15

[16] Aydoan S, Güne B and Gülçiçek Ç 2003 The Misconceptions about Heat and Temperature Journal of Gazi education faculty 23 111124

[17] Aldila W Y, Setyarsih W and Kholiq A 2016 Penggunaan PhET Simulation dalam ECIRR untuk Mereduksi Miskonsepsi Siswa pada Materi Fluida Dinamis Jurnal Inovasi Pendidikan Fisika (JIPF) 5 161–4

[18] Gafoor K A 2016 Misconception in physics among secondary school students Journal of Indian Education 34 77-90

[19] Gaston R J and Bell S E 1986 No Title. The Informal Supply of Capital (1978) 199–207

[20] Marks R B, Sibley S D and Arbaugh J B 2005 A structural equation model of predictors for effective online learning Journal of Management Education 29 https://doi.org/10.1177/1052562904271199

[21] Sari D P, Sutrisno L and Oktaviany E 2013 Deskripsi miskonsepsi siswa tentang rumus-rumus Fisika kelas VII SMP Khatulistiwa Jungkat 2 1–10

[22] Treagust D F 1988 Development and use of diagnostic tests to evaluate students’ misconceptions in science International Journal of Science Education 10 159–69 https://doi.org/10.1080/0950069880100204

[23] Ujian S, Sma, N., Kabupaten, D. I., Siotapina, S. M. A. N., Sulawesi, B., Universitas, T., & Yogyakarta, N. (2015). No Title, 3(2), 123–133.

[24] Angin S L, Paro and Sutopo 2017 Pemahaman Mahasiswa Tentang Multirepresentasi Konsep Percepatan Jurnal Riset & Kajian Pendidikan Fisika 4 48–53

[25] Ardianti A D and Sa’ida I A 2018 Pengembangan tes diagnostik untuk mendeteksi miskonsepsi mahasiswa pada materi usaha dan energi Ed-Humanistics Jurnal Ilmu Pendidikan 3 256-61

[26] Kurniasih M D 2017 Analisis miskonsepsi mahasiswa Program Studi Pendidikan Fisika menggunakan Certainty Of Response Index ( CRI ) pada konsep Gaya EduSains 4 29–38

[27] Pascasarjana P and Syiah U 2017 Identifikasi miskonsepsi mahasiswa calon guru Fisika pada Pokok Bahasan Rangkaian Listrik melalui Certainty of Response
Index Prosiding Seminar Nasional Pascasarjana (SNP) Unsyiah 94–102

[28] Rahmawati D and Syuhendri K W 2014 Analisis Pemahaman Konsep Termodinamika Mahasiswa Pendidikan Fisika Menggunakan Instrumen Survey Of Thermodynamic Processes And First And Second Laws (STPFaSL) Jurnal Ilmu Fisika dan Pembelajarannya 1 17-27.

[29] Taufiq M 2012 Remediasi miskonsepsi mahasiswa calon guru fisika pada konsep gaya melalui penerapan model siklus belajar (Learning cycle) 5E Jurnal Pendidikan IPA Indonesia 1 198–203 https://doi.org/10.15294/jpii.v1i2.2139

[30] Tiandho Y 2018 Miskonsepsi gaya gesek pada mahasiswa Jurnal Pendidikan Fisika dan Keilmuan 4 1–9 https://doi.org/10.25s72/jpfk.v4i1.1814

[31] Mosik and Maulana P 2010 Usaha mengurangi terjadinya miskonsepsi fisika melalui pembelajaran dengan pendekatan konflik kognitif Jurnal Pendidikan Fisika Indonesia 6 98–103

[32] Arsyad A A and Sartika D 2012 Identifikasi miskonsepsi pada materi gaya gesek Jurnal Sains Fisika 2 101-4

[33] Kartal T, Öztürk N and Yalvaç H G 2011 Misconceptions of science teacher candidates about heat and temperature Procedia - Social and Behavioral Sciences 15 2758–63 https://doi.org/10.1016/j.sbspro.2011.04.184

[34] Suliyanaht, Putri H N P A and Rohmawati L 2018 Identification student’s misconception of heat and temperature using three-tier diagnostic test Journal of Physics: Conference Series 997 https://doi.org/10.1088/1742-6596/997/1/012035

[35] Diyanahesa N E-H, Kusairi S and Latifah E 2017 Development of misconception diagnostic test in momentum and impulse using isomorphic problem Journal of Physics: Theories and Applications 1 145 https://doi.org/10.20961/jphystheor-appl.v1i2.19314

[36] Zukhruf K D, Khaldun I and Ilyas S 2016 Remediasi Miskonsepsi Dengan Menggunakan Media Pembelajaran Interaktif Pada Materi Fluida Statis Jurnal Pendidikan Sains Indonesia 4 56–68

[37] Bennett D M 2014 British Journal of Psychiatry 205 76–7 https://doi.org/10.1192/bjp.205.1.76a

[38] Ingeç Ş K 2009 Analysing concept maps as an assessment tool in teaching physics and comparison with the achievement tests International Journal of Science Education 31 1897–915 https://doi.org/10.1080/09500690802275820

[39] Adodo S O 2013 Effects of two-tier multiple choice diagnostic assessment items on students’ learning outcome in Basic Science Technology (BST) Academic Journal of Interdisciplinary Studies 2 201–10 https://doi.org/10.5901/ajis.2013.v2n2p201

[40] Bayuni T C, Sopandi W and Sujana A 2018 Identification misconception of primary school teacher education students in changes of matters using a five-tier diagnostic test Journal of Physics: Conference Series 1013 0–7 https://doi.org/10.1088/1742-6596/1013/1/012086

[41] Budiharti R, Radyioyo Y, Rizky N, Nuraini A, Putri H V, Saputro D E and Adhitama E (n.d.) Empat Tahap, Tes Diagnostik, Profil Miskonsepsi 237–49

[42] Chen C C, Lin H S and Lin M L 2002 Developing a two-tier diagnostic instrument to assess high school students’ understanding- the formation of images by plane mirror Proc. Natl. Sci. Counc. ROC(D) 12 106-21

[43] Chu H E, Treagust D F and Chandrasegaran A L 2009 A stratified study of students’ understanding of basic optics concepts in different contexts using a two-tier multiple choice items Research in Science & Technological Education
Chang H P et al 2007 Investigating primary and secondary students’ learning of physics concepts in Taiwan *International Journal of Science Education* 29 465-82

Costu B, Ayas A, Niaz M, Ünal S and Çalik M 2007 Facilitating conceptual change in students’ understanding of boiling concept *Journal of Science Educational Technology* 16 524-36

Akkus H, Kadayifci H and Atasoy B 2011 Development and application of a two-tier diagnostic test to assess secondary students’ understanding of chemical equilibrium concepts *Journal of Baltic Science Education* 10 146-55

Cheong I P A, Treagust D, Kyeleve I J and Oh P Y 2010 Evaluation of students’ conceptual understanding of malaria *International Journal of Science Education* 32 2497-519

Monteiro A, Nobrega C, Abrantes I and Gomes C 2012 Diagnosing Portuguese students’ misconceptions about the mineral concept *International Journal of Science Education* 34 2705-26

Eryilmaz A 2010 Development and application of a three-tier heat and temperature test: Sample of bachelor and graduate students * Eurasian Journal of Educational Research* 40 53-76

Pesman H and Eryilmaz A 2010 Development of a three-tier test to assess misconceptions about simple electric circuits *The Journal of Educational Research* 103 208-22

Kizilcik H S and Günes B 2011 Developing three-tier misconception test about regular circular motion *Hacettepe University Journal of Education* 41 278-92

Fariyani Q, Rusilowati A and Sugianto 2015 Pengembangan Four-Tier Diagnostic Test Untuk mengungkap miskonsepsi Fisika Siswa SMA kelas X Qisthi *Journal of Innovative Science Education* 4 41–9

Ismail I I, Samsudin A, Suhendi E and Kaniawati I 2015 Diagnostik miskonsepsi melalui Listrik Dinamis Four Tier Test *Prosiding Simposium Nasional Inovasi Dan Pembelajaran Sains (SNIPS 2015)* 381–4

Sholihat F N, Samsudin A and Nugraha M G 2017 Identifikasi miskonsepsi dan penyebab miskonsepsi siswa menggunakan Four-Tier Diagnostic Test pada submateri Fluida Dinamik: Azas Kontinuitas *Jurnal Penelitian & Pengembangan Pendidikan Fisika* 3 175–80 https://doi.org/10.21009/1.03208

Zulfikar A, Samsudin A and Saepuzaman D 2017 Pengembangan terbatas Tes Diagnostik Force Concept Inventory berformat Four-Tier Test *Jurnal Wahana Pendidikan Fisika* 2 43–9

Gurel D K, Eryilmaz A and McDermott L C 2015 A review and comparison of diagnostic instruments to identify students’ misconceptions in science *Eurasia Journal of Mathematics, Science and Technology Education* 11 989–1008 https://doi.org/10.12973/eurasia.2015.1369a

Amin N, Samsudin A and Fisika P 2016 Analisis instrumen Tes Diagnostik Dynamic-Fluid Conceptual Change Inventory (DFCCI) bentuk Four-Tier Test pada beberapa SMA di Bandung Raya *Prosidng SNIPS 2016* 570–4

Kaltakçi D 2012 *Development and application of a four-tier test to assess preservice physics teachers’ misconceptions about geometrical optics.* Unpublished PhD Thesis, Middle East Technical University, Ankara, Turkey.

Caleon I S and Subramaniam R 2010b Do students know what they know and what they don’t know? Using a four-tier diagnostic test to assess the nature of students' alternative conceptions *Research in Science Education* 40 313-37

Gurel D K, Eryilmaz A and McDermott L C 2015 A review and comparison of diagnostic instruments to identify students’ misconceptions in science *Eurasia Journal of Mathematics, Science and Technology Education* 11 989–1008 https://doi.org/10.12973/eurasia.2015.1369a
[60] Sreenivasulu B and Subramaniam R 2013 University students’ understanding of chemical thermodynamics *International Journal of Science Education* **35** 601-35

[61] Suparno P 2013 *Miskonsepsi Perubahan Konsep Dalam Pendidikan Fisika.* (Jakarta: Grasindo)

[62] Sutama 2010 Metode Penelitian Pendidikan *Thinking Skills and Creativity* **19** https://doi.org/10.1002/jez.1057

[63] Shui-Te L, Kusuma I W, Wardani S, Harjito 2019 Hasil identifikasi miskonsepsi siswa ditinjau dari aspek Makroskopis, Mikroskopis, dan Simbolik (MMS) pada pokok bahasan Partikulat Sifat Materi di Taiwan *Jurnal Inovasi Pendidikan Kimia* **12** 2019-30

[64] Ericson G and Tiberghien A 1985 Heat and temperature *Children’s Ideas in science* (Philadelphia, PA: Open University Press)

[65] McDermott L C 2003 Improving student learning in sciences *Physical Science News* **4** 6-10

[66] Stuart S A, Brown M I and Draper S W 2004 Using an electronic voting system in logic lectures: one practitioner’s application *Journal of Computer Assisted Learning* **20** 95-102