How interpersonal and generic science skills influence students’ alternative conceptions in learning physics?

M D Trisniarti*, N S Aminah, and S Sarwanto
Program Magister Pendidikan Fisika, Universitas Sebelas Maret, Jl. Ir. Sutami 36 A, Kentingan, Jebres, Surakarta 57126, Indonesia

*Corresponding author’s email: mayangdwinta@student.uns.ac.id

Abstract. The study reports on the cause of misconceptions in physics have not been done in a major area. The source of misconceptions are students, teachers and learning resources. Thus misconceptions are often caused by preconception, reasoning, intuition and associative thinking. This study aimed to find other factors affecting misconceptions that lead to students’ alternative conceptions in learning physics, especially in kinetic theory of gases. The identification of factors affecting that influence students’ misconception was conducted by using a set of responses in the questionnaires and administrated to 16 teachers and 66 students from six senior high schools in Surakarta. Interview to six teachers and twelve students as representatives was also held to support the data from questionnaire result. Misconceptions score were collected from the kinetic theory of gases test to explore students’ alternative conceptions in learning physics. Two genuine factors affecting the cause of misconceptions were identified namely interpersonal skills and generic science skills.

1. Introduction
The main purpose of science education is to conduct teaching and learning process to help students get proper and correct conceptual understanding [1]. Different information owned by students sometimes causes some students to have a concept that is not in accordance with the scientific concepts [2]. Science education in both natural science and physical science is often challenged by misconceptions happened in students in daily basis [3]. A need-based analysis is needed to conduct so the factors affecting students’ misconception in learning physics can be determined by teachers [4].

Misconceptions happen when students have different information owned by students and it leads to the common case that students have a different conceptual framework with the scientific concepts by scientists [5]. Misconceptions occur when concepts that students possess is not in accordance with the concept of experts [6]. This is the case of mismatch in students that often called in different various terms which are can be called using several terms such as “mental model” [7-9] and “alternative conceptions” [10-13]. The term “misconception” and “alternative conception” is used in this study.

Research on misconceptions, underlying causes, their sources, and ways of knowing and reducing them in physics learning has been conducted by several researchers [14-18]. Research on misconceptions that are mostly carried out in physics learning shows that this problem is a very
important thing to deal with. If the problem of misconception can be mapped and investigated in the right way, then sources and causes of misconceptions can also be tracked [19,20].

The things that cause misconceptions that are quoted from several experts, among others: the difficulty of students to abandon pre-existing of conceptual understanding, the application of concepts is not correct based on the concept students have learned, the failure of teachers to display essential aspects of the concept in question, the teachers’ inability to use the terms and usually also due to failure in connecting a concept with other concepts that are different in the right situation [21,22].

As a part of science, physics subjects contain concrete and abstract materials [23]. Abstract topics make students less understand and they experience misconceptions [24]. Kinetic theory of gases is one of the abstract material in physics majors [25]. Broadly speaking, the sources of misconception can be summarized in four groups that often arise, namely: including textbooks, learning process, teachers and students themselves [26,27]. Misconceptions are often caused by preconception, reasoning, intuition, humanistic thinking, associative thinking, development of cognitive level and skills and ability [28]. In the previous study, the prevalence, strength and sources of misconceptions were identified through pretest and post-test as the result has shown that personal experience and media are important sources of misconception to influence strongly held beliefs [29].

This study aims to find other factors affecting that lead to students’ alternative conceptions in learning physics, especially in kinetic theory of gases as the pilot study found that misconceptions often occurred in this chapter. Teachers and students were interviewed and asked to join focus group discussion to confirm that kinetic theory of gases has many cases of misconceptions.

2. Methods
2.1. Participants
Sixteen physics teachers and sixty-six students who take physics major in senior high schools from six senior high school in Surakarta, already learning kinetic theory of gases, agreed and volunteered as participants in this study. Participants provided the consent prior before the study conducted.

2.2. Materials
This study developed a set of open-ended test of kinetic theory of gases to find students’ alternative conceptions in learning physics. The physics open-ended test of this study adopted the design of the previous study [30,31]. The identification of factors affecting that influence students’ misconception was conducted by using a set of responses in the questionnaires and interviews. The questionnaires for teachers were administrated to 16 teachers while the questionnaires for students were administrated to 66 participants. Interviews to 6 teachers and 12 students as representatives were also held to support the data from questionnaires result. The process of this study was recorded under consent.

2.3. Procedure
Participants joined and completed the process in this study during the first class meeting of the second semester in academic year 2018/2019. This study was conducted in four months. Both students and teachers as participants required about two hours to completed the stages of this study.

Participants were given open-ended test in the first stage of study and they had to answer the questions in the answer sheet. The responses answer was divided by five categories of numerical scores. The category of conceptual understanding can be seen in Table 1 [32].
Table 1. Evaluation scheme for students’ conceptual understanding

| Numerical score and degree of conceptual understanding | Criteria for scoring                                                                 |
|-----------------------------------------------------|--------------------------------------------------------------------------------------|
| 0-No understanding (NU)                             | Blank, repeats question, irrelevant or unclear response, no explanation given for choice answer |
| 1-Specific misconception (SM)                       | Scientifically incorrect responses that arises from different concept of scientific concepts |
| 2-Partial understanding with a specific misconception (PUSM) | Responses that show understanding of the concept, but that also contain a misconception |
| 3-Partial understanding (PU)                         | Responses that contain a part of the scientifically accepted concept                  |
| 4-Scientific understanding (SU)                      | Responses that contain all parts of the scientifically accepted concept               |

3. Result and Discussion

The results of students’ misconception through the level of conceptual understanding were taken from the open-ended test. Students were given 15 questions and they gave the responses directly after they finished the test. The pattern of alternative conceptions in students when learning physics were identified through the open-ended test. Then, the study conducted questionnaires and interviews session to identify the factor affecting students’ misconceptions.

3.1. Level of physics conceptual understanding in students through open-ended test

Students were given open-ended test through 15 questions to work on understanding the relationship of pressure (P), volume (V) and temperature (T) as the important parameters in kinetic theory of gases. Students could give the answers based on their conceptual understanding in point (f) if they have held other concepts. The answers then were analyzed one by one through all of questions.

Based on the physics open-ended test results on chapter kinetic theory of gases, none of the students held the correct answers in all of the questions. The level of students’ conceptual understanding were classified through the four categories as seen in Table 2.

Table 2. Students’ conceptual understanding based on the open-ended test result

| Item test | NU | % | SM | % | PUSM | % | PU | % | SU | % |
|-----------|----|---|----|---|------|---|----|---|----|---|
| 1         | 13 | 19.70 | 26 | 39.39 | 8 | 12.12 | 11 | 16.67 | 8 | 12.12 |
| 2         | 15 | 22.73 | 15 | 22.73 | 17 | 25.76 | 8 | 12.12 | 11 | 16.67 |
| 3         | 14 | 21.21 | 26 | 39.39 | 4 | 6.06 | 15 | 22.73 | 7 | 10.61 |
| 4         | 11 | 16.67 | 25 | 37.88 | 12 | 18.18 | 8 | 12.12 | 10 | 15.15 |
| 5         | 10 | 15.15 | 30 | 45.45 | 3 | 4.55 | 14 | 21.21 | 9 | 13.64 |
| 6         | 20 | 30.30 | 28 | 42.42 | 0 | 0.00 | 6 | 9.09 | 12 | 18.18 |
| 7         | 34 | 51.52 | 13 | 19.70 | 6 | 9.09 | 3 | 4.55 | 10 | 15.15 |
| 8         | 17 | 25.76 | 31 | 46.97 | 5 | 7.58 | 5 | 7.58 | 8 | 12.12 |
| 9         | 22 | 33.33 | 21 | 31.82 | 14 | 21.21 | 9 | 13.64 | 0 | 0.00 |
| 10        | 9  | 13.64 | 19 | 28.79 | 16 | 24.24 | 10 | 15.15 | 12 | 18.18 |
| 11        | 16 | 24.24 | 15 | 22.73 | 9 | 13.64 | 6 | 9.09 | 20 | 30.30 |
| 12        | 19 | 28.79 | 23 | 34.85 | 1 | 1.52 | 12 | 18.18 | 11 | 16.67 |
| 13        | 26 | 39.39 | 11 | 16.67 | 8 | 12.12 | 9 | 13.64 | 12 | 18.18 |
| 14        | 14 | 21.21 | 22 | 33.33 | 9 | 13.64 | 1 | 1.52 | 20 | 30.30 |
Based on the Table 2, it can be seen that students were more likely to have “no understanding” and “specific misconception” level of conceptual understanding. Students experienced misconceptions as they held alternative conceptions on the item test number 1, 3, 4, 5, 6, 8, 9, 12, 14 and 15. Each question has its own identification based on the sub-topic on chapter kinetic theory of gases. It can also be seen that students held alternative conceptions mostly in sub-topic the law of ideal gases.

3.2. The students’ alternative conceptions profile on kinetic theory of gases
The students’ alternative conceptions profile was then identified based on the answer sheet results. The profile of students’ alternative conceptions on kinetic theory of gases were classified based on the sub-topic which are: (1) properties of ideal gas, (2) the law of ideal gases, (3) ideal gas state equation, (4) kinetic energy of gases and (5) equipartition of energy. Figure 1 showed the percentage on how the level of students’ conceptual understanding stood on chapter kinetic theory of gases. Each sub-topic then were analyzed through the results based on the samples of item test number which have high percentage of students’ misconceptions which were 1, 3, 6, 9 and 14.

![Figure 1](chart.png)

**Figure 1.** The students’ alternative conceptions profile based on sub-topic

Item number 1 was to identify students’ conceptual understanding on the relationship between volume (V) and temperature (T) as properties on state of ideal gas. It is the fist sub-topic on chapter kinetic theory of gases. Students were given a piston that is heated to a certain temperature and a thermometer is installed to measure the temperature. Students were asked to predict within the volume of the air column in a tube where the pressure is held constant and the temperature can be adjusted. The results showed that students considered the volume in the air column to be smaller when the temperature is raised. The concept is not right. Volume is a function variable of temperature. If the temperature increases, the volume will also increase (constant pressure state) [33].

Item number 3 was to identify students’ conceptual understanding on the law of ideal gases. In the results of the question, students tend to consider the pressure in the air column to be influenced by the pressure given by the piston. This question aims to identify students’ conceptual understanding of gas law of Boyle. Boyle stated that the equation PV = C applies (C is a constant). The pressure given by the piston causes the volume in the piston to decrease, so that the pressure inside the piston increases because the pressure is inversely proportional to the volume at constant temperature [34].

Item number 6 was to identify students’ conceptual understanding on ideal gas state equation. The results of the question number 6 show that students tend to think that the increased temperature due to the sun will affect the tire material so that the air inside the tire can enter. Temperature will tend to affect gas rather than solid material. The increase in temperature will affect the pressure and / or volume of a gas, according to the ideal gas state equation PV = nRT. If one variable cannot increase, the other variables will increase. For example, because the temperature continues to increase the volume of gas inside, the tire will increase which will cause the tire to expand. However, due to
limited tires to expand, the volume will stop increasing. When the temperature continues to increase, the pressure in the tire will increase. This is what causes the tire to explode [35].

Item number 9 was to identify students’ conceptual understanding on kinetic energy of gases. When balloons are inserted into two liquids in a tube container with different temperatures, many students incorrectly deduced what happened to the balloon. In accordance with the gas law of Charles in closed spaces, if the gas pressure is constant, the temperature is directly proportional to the volume. In tube A, with a liquid temperature of 100 degrees Celsius, the balloon expands because the heat energy from outside the balloon is transferred into the balloon, so the balloon expands. In tube B, the liquid temperature is smaller than the temperature of the balloon, the heat energy of the balloon is transferred out of the balloon. That is why the balloon on the B tube shrinks [36].

Item number 14 was to identify students’ conceptual understanding on equipartition of energy. Many students assumed that the volume of balloon A is greater than the volume of balloon B, because the distance between molecules making up liquid is greater than the distance between molecules of gaseous substances. The volume of balloon A is indeed greater than the volume of balloon B, because the distance between the molecules making up the liquid is smaller than the distance between the molecules of the gas substance. The density of a substance is defined as the mass per unit or because the distance between the molecules making up a gas is greater, it can be said that the gas density is smaller than the density of the liquid. This is because for one unit of the same volume there will be fewer molecules making up the gas than the molecules making up the liquid [37].

3.3. The cause of students’ alternative conceptions affecting performance on the open-ended test

Physics teachers in Surakarta are more likely to hold paper test to know students’ cognitive level using formative test. Whereas there are no method concerning to map and investigate misconceptions happened in learning physics. The questionnaires results conducted for participants showed that the causes of students’ misconceptions according to were preconception, reasoning, intuition, humanistic thinking, associative thinking, development of cognitive level, learning interests and skills and abilities. Students also stated that they have difficulties in learning physics as the initial concepts were incorrect.

Based on the results from questionnaires and interviews to participants, the cause of students’ alternative conceptions based on sub-topic on chapter kinetic theory of gases were created a set of patterns like shown in Figure 2. They were varied on each sub-topic.

![Figure 2. Students’ alternative conceptions based on sub-topic on chapter kinetic theory of gases](image-url)
Figure 2 also showed that skills and ability have affected the most of students’ alternative conception. Whereas two genuine sub-factors affecting the cause of misconceptions were identified namely interpersonal skills and generic science skills. Based on the questionnaires and interviews, students were more likely to have varied interpersonal and generic science skills which they did not realize that these factors affecting have big impacts on how they think in learning physics.

3.4. How interpersonal skill influence students’ alternative conceptions in learning physics
Participants in this study completed the questionnaires and interviews section. The results showed that students experienced misconceptions as they do not have the courage of asking and answering the questions and problems given at the classroom. So, they experienced difficulty in understanding the physics conceptual framework and they held alternative conceptions. Students were also competing with their friends, not collaborating instead. The way students took the physics classroom in condescending environment making them difficult to have scientific understanding. When they did not understand the concepts, they would just leave it all the rest. Whereas abstract materials like kinetic theory of gases need to be discussed deeper so that students are able to hold scientific concepts in a correct way.

By the results taken, the score of students’ alternative conceptions were taken to determine whether interpersonal skills affected overall test performance done by students. The calculated results using one way ANAVA was done. A mean accuracy rate of 40.23% at the open-ended results on chapter kinetic theory of gases had been determined. Thus, the results showed that interpersonal skills influence students’ alternative conceptions in learning physics ($F_{\text{obs}} = 4.592 > F_{\text{table}} = F_{0.05;1;62} = 4.001$, $p = 0.05$, $\eta^2 = 0.31$).

3.5. How generic science skill influence students’ alternative conceptions in learning physics
Participants in this study completed the questionnaires and interviews section. The results showed that students experienced misconceptions as they held alternative conceptions because they were unable to differ symbolic language and define the correct scale in learning physics. Although students are able to perform direct and indirect observation, students were too slow to understand the use of basic obedience logic framework, especially when they were given open-ended test like this study done. Students were answering the questions in a complicated term instead of the simple one. The inference logic was also the parameters of generic science skills indicators that were not be done by students while cause and effect in several questions of kinetic theory of gases, especially in the law of ideal gas.

By the results taken, the score of students’ alternative conceptions were taken to determine whether generic science skills affected overall test performance done by students. The calculated results using one way ANAVA was done. A mean accuracy rate of 40.23% at the open-ended results on chapter kinetic theory of gases had been determined. Thus, the results showed that generic science skills influence students’ alternative conceptions in learning physics ($F_{\text{obs}} = 7.974 > F_{\text{table}} = F_{0.05;1;62} = 4.001$, $p = 0.05$, $\eta^2 = 0.12$).

4. Conclusion
The conclusion of this study were: (1) interpersonal skills influence students’ alternative conceptions in learning physics ($F_{\text{obs}} = 4.594 > F_{\text{table}} = F_{0.05;1;62} = 4.001$), (2) generic science skills influence students’ alternative conceptions in learning physics ($F_{\text{obs}} = 70.974 > F_{\text{table}} = F_{0.05;1;62} = 4.001$), and (3) there was no interaction between interpersonal skills and generic science skills to influence students’ alternative conceptions in learning physics ($F_{\text{obs}} = 0.398 > F_{\text{table}} = F_{0.05;1;62} = 4.001$). Both factors affecting has its own influence on students’ misconceptions in learning physics, especially on chapter of kinetic theory of gases.
5. References
[1] Guthrie JT 2004 Classroom contexts for engaged reading: An overview. Motivating reading comprehension: Concept-oriented reading instruction 1-24
[2] Jauhariyah MN, Suprapto N, Admoko S, Setyarsih W, Harizah Z and Zulfa I 2018 Journal of Physics: Conf. Series 997 1 012031
[3] Foisy LM, Potvin P, Riopel M and Masson S 2015 Is inhibition involved in overcoming a common physics misconception in mechanics? Trends in Neuroscience and Education 41-2 26-36
[4] Santrock J W 2014 Educational Psychology, 5th ed. (New York: McGraw Hill Education)
[5] Driver R, Asoko H, Leach J, Scott P and Mortimer E 1994 Educ. Res. 23 5-12
[6] Chhabra M and Baveja B 2012 Exploring Minds: Alternative Conceptions in Science. Procedia-Social and Behavioral Sciences 55 1069-78.
[7] Özcan O and Gercèk C 2015 Students’ Mental Models of Light to Explain the Compton Effect. Procedia-Social and Behavioral Sciences 191 pp.2195-7.
[8] Aşıç HB, Tan FZ and Altıntaş F 2016 A Strategic Approach for Learning Organizations: Mental Models Procedia-Social and Behavioral Sciences 235 pp.2-11.
[9] Goodhew J, Pahl S, Goodhew S and Boomsma C 2017 Mental models: Exploring how people think about heat flows in the home Energy research & social science 31 pp.145-57.
[10] Kolomuc A, Ozmenn H, Metin M and Acıslı S 2012 The effect of animation enhanced worksheets prepared based on 5E model for the grade 9 students on alternative conceptions of physical and chemical changes Procedia-Social and Behavioral Sciences 46 1761-5.
[11] Hussain NH, Latiff LA and Yahaya N 2012 Alternative conception about open and short circuit concepts Procedia-Social and Behavioral Sciences 56 466-73
[12] Narjaiaew P 2013 Alternative conceptions of primary school teachers of science about force and motion Procedia-Social and Behavioral Sciences 88 250-7
[13] Wenning C J 2008 Dealing more effectively with alternative conceptions in science Journal of Physics Teacher Education Online 5 1 11-9
[14] Alwan A A 2011 Proc. Soc. Behav. Sci. 12 600-614
[15] Handhika J, Cari C, Suparmi S and Sunarno W 2017 Journal of Physics: Conference Series 795 1 p. 012058
[16] Kahar M S, Wekke I S, Ibrahim I, Amri I and Pristianto H 2019 AIP Conference Proceedings 2081 1 p. 030026
[17] Kanlı U 2014 Eurasia Journal of Mathematics, Science & Technology Education 10 5
[18] Martin-Blas T, Seidel and Serrano-Fernandez A 2010 European Journal of Engineering Education 35 6 pp.597-606
[19] Mbatha BT, Ocholla DN and Roux JL 2011 Diffusion and adoption of ICTs in selected government departments in KwaZulu-Natal, South Africa Information Development 27 4 pp. 251-63
[20] Arslan H O, Cigdemoglu C, and Moseley C 2012 Int. J. of Sci. Ed. 34 1667–1686
[21] Ratnasari D, Sukarmin S, Suparmi S and Aminah NS 2017 Journal of Physics: Conference Series 895 1 p. 012044
[22] Amran A, Perkasa M, Satriawan M, Jasir I and Irwansyah M 2019 Journal of Physics: Conf. Series 1157 2 p. 022025
[23] Anri Y, Maknun J and Chandra D T 2018 Journal of Physics: Conf. Series 1013 012058
[24] Kautz C H, Heron P R L, Loverude M E and McDermott L C 2005 Am. J. Phys. 73 1055-63
[25] Nurhuda T, Rusdiana D and Setiawan W 2017 Journal of Physics: Conf. Series 812 012105
[26] Ragan TJ and Smith PL 1999 Instructional design (New York: Macmillan Publishing Company)
[27] Caleon I S and Subramaniam R 2010 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 3 pp. 313-37
[28] Kordaki M and Psomos P 2015 Diagnosis and treatment of students’ misconceptions with an intelligent concept mapping tool Procedia-Social and Behavioral Sciences pp. 838-42.
[29] Taylor A K and Kowalski P 2004 The Psychological Record 54 15-25
[30] Saputro D E, Sarwanto S and Sukarmin S 2019 Journal of Physics: Conf. Series 1157 032018
[31] Gusmida R and Islami N 2017 Journal of Educational Sciences 1 1-10
[32] Fariyani Q, Rusilowati A and Sugianto S 2017 Four-Tier Diagnostic Test to Identify Misconceptions in Geometrical Optics Unnes Science Education Journal 6 3
[33] Tipler P A 1991 Physics for scientist and engineer, 3rd ed. (New York: Worth Publisher, Inc)
[34] Serway R A and Jewett J W 2004 Physics for scientists and engineers, 6th ed. (Singapore: Thomson Books)
[35] Kohn W 1999 An essay on condensed matter physics in the twentieth century Reviews of Modern Physics 71 59-70
[36] Kispert L D, Bowman M K, Norris J R and Brown M S 1982 Electron spin echo studies of the internal motion of radicals in crystals: Phase memory vs correlation time The Journal of Chemical Physics. 76 1 pp. 26-30
[37] Renström L, Andersson B and Marton F 1990 Students’ conceptions of matter Journal of Educational Psychology 82 3 p.555.

Acknowledgments
The writers would like to acknowledge HPI for the support, parents for the encouragement and Firmansyah for the assistance during the research conducted.