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Students' Problem-Solving Abilities in Temperature and Heat Topic

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***Abstract*—** Problem-solving skills are required to understand and find the solution of problems related to physics concepts. This research intended to analyze students' problem-solving skills in the temperature and heat topics. The study was done by using descriptive design method with 31 students of a high school in Malang, Indonesia. Data were gathered through students' written work in open-ended problems. The problem-solving indicators employed in the study were useful description, application of physics, mathematical procedures appropriateness, and logical progression. The data were analyzed quantitatively using statistics descriptive method. The results showed that the students' problem-solving skills was still relatively low, as indicated by the use of incomplete problem-solving indicators. Most students were only able to solve problems using several indicators, i.e. useful description, physics approach dan mathematical procedures appropriately.

***Keywords*—** problem-solving, heat, temperature, preliminary study

I. INTRODUCTION

The current teaching and learning setting should enable students to achieve the 21st century skills goals, to ensure their flexibility in global challenge global challenge. Problem solving is one of the 4C essential skills in 21st century [1]&[2]. It is a complex process that can be exercised through the instructional design [3]&[4].

The lack of problem solving skills were due to the lack of conceptual understanding, since to solve a problem effectively, a comprehensive understanding of concepts is needed [4]&[5]. Accordingly, problem solving can be employed to evaluate the students' conceptual understanding [6]–[8], including in physics classroom. When the students cannot provide a complete problem solving, it means their understanding is incomplete as well [9]&[10]. Other relevant skills in problem solving are identification, figuration, determination, evaluation, organization and consideration of various alternative to find the solution [11].

As they play important role for students' thinking development and their knowledge implementation, teachers need to ensure the establishment of the problem-solving skills. Before selecting the right treatment for supporting the students' mastery in problem solving, it is important to understand the current condition of students in term of their abilities in solving a problem. Therefore, the preliminary study to identify the problem-solving abilities of students is highly needed.

Therefore, in the present study, problem solving's level of the students were elaborated based on the problem solving indicators which are: their understanding toward the problem (shown by their abilities in writing a useful description), the correctness in selecting physical concepts and specific principles, the flexibilities in working with mathematical expressions and calculations and the skills in arguing logically.

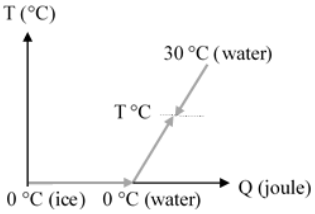
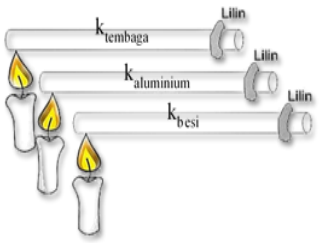
The concept of temperature and heat become the focus of the study since it has a lot of application in real life [12] but a number of studies found students' encountered misconception of this topic [13]&[14]. This study is intended to reveal how the students solving the open-ended questions in physics and how they employ the indicators of problem solving.

To make it easier in identifying students, the participants of the study will be classified as *expert* and *novice* [6]&[15]. The expert consider the appropriate physics concepts during the problem solving [16]&[17]. On the other hand, the novice merely focus on mathematics expression [4]&[18] which lead them to do 'plug and chug' in solving a problem rather than applying concepts [17]&[19]. The 'plug and chug' has become a long problem in physics education as students tend to focus on the numbers and symbols instead of the concepts and how it works in helping them to solve the problem.

II. METHODS

The present study used descriptive method. The subjects were 31 eleventh grade of senior high school students in Malang, Indonesia. The data were gathered through students written work in solving three open-ended questions. The reliability of the instrument was 0.756. The problems can be observed in Table 1.

TABLE 1. OPEN-ENDED QUESTIONS

Topics	Problem-solving Questions
Thermal Expansion	In temperature 25ºC, A copper vessel with 81 cm^3 capacity is filled with water. It was heated to 100ºC such that the water spilled out from the vessel. If the α_{cooper} = 1.8 × 10^{-5}/ºC and γ_{water} = 4.4 × 10^{-4}/ °C, calculate the amount of water that spilled out of the vessel due to the change of the temperature?
Black Latent Heat	 In a hot-sunny day, Mrs. Endang plan to serve ice tea by combining 30 gram ice cubes of 0ºC into a glass of 200 gram water of 30ºC. Suppose the glass cannot absorb the heat, what will be the final temperature of ice tea? Consider the graph given to show the mixture combination (Latent heat of fusion of ice = 336 × 103 J/kg, specific heat capacity of water = 4200 J/kg °C).
Heat Transfer	 Three types of metal consist of copper, iron and aluminum have the same initial temperatures and sizes. However these materials have different thermal conductivity (k) where $k_{cooper} > k_{aluminum} > k_{iron.}$ In every end of the metal, a candle was buried in the same time with same temperature. If m gram of the candle in aluminum melted, determine the possibility gram of melted on two other candles.

After the students finished the problems, they were classified based on their problem-solving abilities. The indicators used in the present study is based on five aspects as follow: (1) useful description, in which the students organize the information given in the problem, (2) physics approach, in which the students select appropriate principles to solve the problem, (3) specific application of physics, in which the students determine what kind of specific principles that work on certain condition, (4) mathematical procedures appropriatness, in which the students able to perform basic mathematics needed and (5) logical progression, in which the students able to present their arguments and reasons meaningfully [16].

III. RESULTS AND DISCUSSION

There were three open-ended questions related to temperature and heat topic given in the test. Consider the results in the Table 2 to Table 4.

TABLE 2. STUDENTS' PROBLEM SOLVING FOR PROBLEM 1

Problem-solving Indicators	Problem 1 (Thermal Expansion)					
	5	**4**	**3**	**2**	**1**	**0**
UD	14	17	0	0	0	0
PA	0	2	0	0	0	29
SAP	0	7	24	0	0	0
MPA	0	7	23	1	0	0
LP	0	1	5	25	0	0

TABLE 3. STUDENTS' PROBLEM SOLVING FOR PROBLEM 2

Problem-solving Indicators	Problem 2 (Black Latent Heat)					
	5	**4**	**3**	**2**	**1**	**0**
UD	22	9	0	0	0	0
PA	0	0	1	0	0	30
SAP	0	0	1	16	0	14
MPA	0	0	21	3	0	7
LP	0	0	1	23	0	7

TABLE 4. STUDENTS' PROBLEM SOLVING FOR PROBLEM 3

Problem-solving Indicators	Problem 3 (Heat Transfer)					
	5	**4**	**3**	**2**	**1**	**0**
UD	0	31	0	0	0	0
PA	23	0	1	0	0	7
SAP	0	1	0	0	0	30
MPA	0	0	0	0	0	31
LP	0	0	0	8	0	23

Note: UD = Useful Description, PA = Physics Approach, SAP = Specific Application of Physics, MPA = Mathematical Procedures Appropriately, and LP = Logical Progression

Table 2, Table 3 and Table 4 provide an insight that most of students merely able to do the Useful Description process. According to prior studies, this is due to the lack of skills in solving more complex problems [17]&[20]. They also found it is difficult to implement the physics concepts in solving the problem [21]&[22]. In general, the students have adequate skill in mathematics that support their counting, even though a number of errors were occurred. Based on this results, most of the students can be classified as novice problem solvers [8]&[9].

We classified the students' work into two categories: novice and expert. The novice students performed single indicator of the problem solving since they merely use mathematical procedures without grounding concept while the expert combine some indicators in the proposed solution. The following figure provides the example of students (novice and expert) categories in solving Latent Heat (principle of Joseph Black) problem.

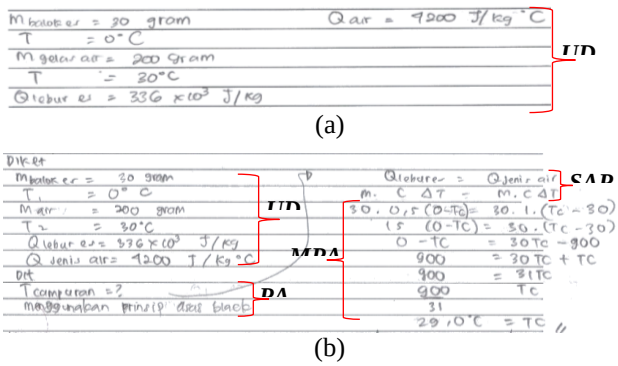


Fig.1. The comparison of novice (a) and expert (b) students in problem solving

Fig.1 shows the novice student provided the responses in form of description of the given information and what is

asked in the problem (UD). On the other hand, the expert students provided responses with UD, PA, SAP and MPA indicators. Overall, the students' performance based on the problem-solving indicators can be seen in Fig.2.

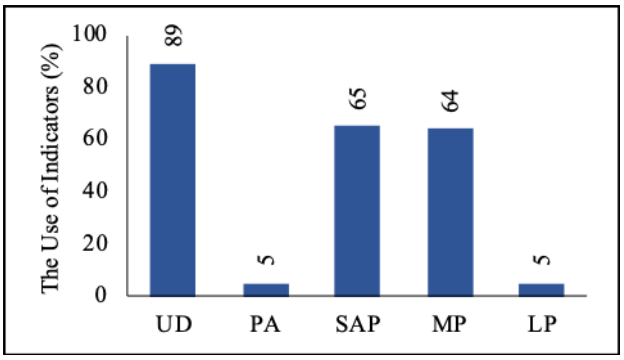


Fig.2. Type of Students' Problem-Solving Indicators

Fig.2. presents that most students were engaged in UD, followed by SAP and MP indicators. The students' PA and LP skills were extremely low. It means that most of the students were able to gather the information given on the problem, but not in using the relevant concepts of temperature and heat. Also, they preferred to use the plug-and-chug approach. It is usually employed by the students with good mathematics foundation which enables them to manipulate the calculation but not implement the appropriate concept [23]. Another studies found that the students usually use logic to solve the physics related problems compared to the actual concept [16]&[24].

Reflecting to the result of the study, it is important for teachers to provide limited guidance in learning, to bridge the students' prior knowledge and logic to the formal concept. The previous studies found that scaffolding and guidance questions enable teachers to facilitate students' conceptual construction and problem solving without stopping their thinking process [25], [26]&[27].

IV. CONCLUSION

The study revealed that the students' problem-solving abilities are low. It can be inferred from the incomplete indicator of problem-solving performed in the written test. Most of the students merely able to use some indicators, usually the Useful Description, Specific Application of Physics and Mathematical Procedures Appropriately. From the results it is clear that physics classroom needs to focus more in the development of students' problem-solving skills.

REFERENCES

[1] S. Handajani, H. Pratiwi, and M. Mardiyana, "The 21st Century skills with Model Eliciting Activities on Linear Program," *J. Phys. Conf. Ser.*, vol. 1008, no. 1, 2018, doi: 10.1088/1742-6596/1008/1/012059.

[2] C. Kivunja, "Exploring The Pedagogical Meaning and Implications of The 4Cs 'Super Skills' for the 21th Century through Bruner's 5E Lenses of Knowledge Construction to Improve Pedagogies ofThe New Learning Paradigm," *Creat. Educ.*, vol. 06, no. 02, pp. 224–239, 2015, doi: 10.4236/ce.2015.62021.

[3] J. L. Docktor and K. Heller, "Robust Assessment Instrument for Student Problem Solving," in *Proceedings of the NARST 2009 Annual Meeting*, 2009.

[4] J. L. Docktor and J. P. Mestre, "Synthesis of Discipline-based Education Research in Physics," *Phys. Rev. Spec. Top. - Phys. Educ. Res.*, vol. 10, no. 2, p. 020119, Sep. 2014, doi: 10.1103/PhysRevSTPER.10.020119.

[5] S.-Y. Lin and C. Singh, "Effect of Scaffolding on Helping Introductory Physics Students Solve Quantitative Problems Involving Strong Alternative Conceptions," *Phys. Rev. Spec. Top. - Phys. Educ. Res.*, vol. 11, no. 2, p. 020105, Aug. 2015, doi: 10.1103/PhysRevSTPER.11.020105.

[6] M. M. Hull, E. Kuo, A. Gupta, and A. Elby, "Problem-solving Rubrics Revisited: Attending to the Blending of Informal Conceptual and Formal Mathematical Reasoning," *Phys. Rev. Spec. Top. - Phys. Educ. Res.*, vol. 9, no. 1, p. 010105, Feb. 2013, doi: 10.1103/PhysRevSTPER.9.010105.

[7] B. Ibrahim and N. S. Rebello, "Role of Mental Representations in Problem Solving: Students' Approaches to Nondirected Tasks," *Phys. Rev. Spec. Top. - Phys. Educ. Res.*, vol. 9, no. 2, p. 020106, Jul. 2013, doi: 10.1103/PhysRevSTPER.9.020106.

[8] Q. X. Ryan, E. Frodermann, K. Heller, L. Hsu, and A. Mason, "Computer Problem-solving Coaches for Introductory Physics: Design and Usability Studies," *Phys. Rev. Phys. Educ. Res.*, vol. 12, no. 1, p. 010105, Feb. 2016, doi: 10.1103/PhysRevPhysEducRes.12.010105.

[9] M. Ceberio, J. M. Almudí, and Á. Franco, "Design and Application of Interactive Simulations in Problem-Solving in University-Level Physics Education," *J. Sci. Educ. Technol.*, vol. 25, no. 4, pp. 590–609, Aug. 2016, doi: 10.1007/s10956-016-9615-7.

[10] S. Rahayu, S. K. Handayanto, S. Zulaikah, and S. Ahda, "Students' Regulation of Cognition in Physics Problem-solving," *J. Phys. Conf. Ser.*, vol. 1097, no. 1, p. 012029, Sep. 2018, doi: 10.1088/1742-6596/1097/1/012029.

[11] S. Zubaidah, "Keterampilan Abad Ke-21: Keterampilan yang Diajarkan Melalui Pembelajaran," in *Seminar Nasional Pendidikan*, 2016, vol. 21, no. 10, pp. 1–17.

[12] D. Gurcay and E. Gulbas, "Determination of Factors Related to Students' Understandings of Heat, Temperature and Internal Energy Concepts," *J. Educ. Train. Stud.*, vol. 6, no. 2, p. 65, 2018, doi: 10.11114/jets.v6i2.2854.

[13] F. N. Nabilah, J. Maknun, M. Muslim, A. Samsudin, L. Hasanah, and A. Suhandi, "Eleventh-grade student's conceptions about temperature and heat," *J. Phys. Conf. Ser.*, vol. 1280, no. 5, 2019, doi: 10.1088/1742-6596/1280/5/052067.

[14] Suliyanah, H. N. P. A. Putri, and L. Rohmawati, "Identification student's misconception of heat and temperature using three-tier diagnostic test," *J. Phys. Conf. Ser.*, vol. 997, no. 1, 2018, doi: 10.1088/1742-6596/997/1/012035.

[15] A. E. Leak, S. L. Rothwell, J. Olivera, B. Zwickl, J. Vosburg, and K. N. Martin, "Examining Problem Solving in Physics-intensive Ph.D. Research," *Phys. Rev. Phys. Educ. Res.*, vol. 13, no. 2, p. 020101, Jul. 2017, doi: 10.1103/PhysRevPhysEducRes.13.020101.

[16] J. L. Docktor *et al.*, "Assessing Student Written Problem Solutions: A Problem-Solving Rubric with Application to Introductory Physics," *Phys. Rev. Phys. Educ. Res.*, vol. 12, no. 1, p. 010130, May 2016, doi: 10.1103/PhysRevPhysEducRes.12.010130.

[17] L. N. Walsh, R. G. Howard, and B. Bowe, "Phenomenographic Study of Students' Problem Solving Approaches in Physics," *Phys. Rev. Spec. Top. - Phys. Educ. Res.*, vol. 3, no. 2, p. 020108, Dec. 2007, doi: 10.1103/PhysRevSTPER.3.020108.

[18] M. De Cock, "Representation Use and Strategy Choice in Physics Problem Solving," *Phys. Rev. Spec. Top. - Phys. Educ. Res.*, vol. 8, no. 2, p. 020117, Nov. 2012, doi: 10.1103/PhysRevSTPER.8.020117.

[19] L. Ding, N. Reay, A. Lee, and L. Bao, "Exploring the Role of Conceptual Scaffolding in Solving Synthesis Problems," *Phys. Rev. Spec. Top. - Phys. Educ. Res.*, vol. 7, no. 2, p. 020109, Oct. 2011, doi: 10.1103/PhysRevSTPER.7.020109.

[20] D. Rosengrant, A. Van Heuvelen, and E. Etkina, "Do Students Use and Understand Free-body Diagrams?," *Phys. Rev. Spec. Top. - Phys. Educ. Res.*, vol. 5, no. 1, p. 010108, Jun. 2009, doi: 10.1103/PhysRevSTPER.5.010108.

[21] C. Riantoni, L. Yuliati, N. Mufti, and N. Nehru, "Problem Solving Approach in Electrical Energy and Power on Students as Physics Teacher Candidates," *J. Pendidik. IPA Indones.*, vol. 6, no. 1, pp. 55–62, Apr. 2017, doi: 10.15294/jpii.v6i1.8293.

[22] L. Yuliati, C. Riantoni, and N. Mufti, "Problem Solving Skills on Direct Current Electricity through Inquiry-Based Learning with PhET Simulations," *Int. J. Instr.*, vol. 11, no. 4, pp. 123–138, Oct. 2018, doi: 10.12973/iji.2018.1149a.

[23] P. B. Kohl and N. D. Finkelstein, "Effects of Representation on Students Solving Physics Problems: A Fine-grained Characterization," *Phys. Rev. Spec. Top. - Phys. Educ. Res.*, vol. 2, no. 1, p. 010106, May 2006, doi: 10.1103/PhysRevSTPER.2.010106.
[24] A. J. Mason and C. Singh, "Surveying College Introductory Physics Students' Attitudes and Approaches to Problem Solving," *Eur. J. Phys.*, vol. 37, no. 5, p. 055704, Sep. 2016, doi: 10.1088/0143-0807/37/5/055704.
[25] I. N. Gita and R. A. Apsari, "Scaffolding in problem based learning to increase students' achievements in linear algebra," *J. Phys. Conf. Ser.*, vol. 1040, no. 1, 2018, doi: 10.1088/1742-6596/1040/1/012024.
[26] R. D. Vale, "The value of asking questions," *Mol. Biol. Cell*, vol. 24, no. 6, pp. 680–682, 2013, doi: 10.1091/mbc.E12-09-0660.
[27] L. Dong, W. T. Seah, and D. Clarke, "Pedagogical tensions in teacher's questioning practices in the mathematics classroom: A case in mainland China," *Eurasia J. Math. Sci. Technol. Educ.*, vol. 14, no. 1, pp. 167–181, 2018, doi: 10.12973/ejmste/79630.