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THE IMPROVEMENT OF PROBLEM-SOLVING SKILLS AND PHYSICS CONCEPT MASTERY ON TEMPERATURE AND HEAT TOPIC

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ABSTRACT

This work aimed at knowing the improvement of problem-solving and physics concept mastery by using the learning model of Hints and Peer Interaction Learning (HPIL) model. This research used embedded experimental model design, that one class could be used as a sample even though the sample size was less than 30 students. The number of the research sample was 22 students of one of the Senior High Schools in Malang. The instruments used were 25 numbers consisting of five numbers of the essay (problem-solving skill) and 20 numbers of multiple choices items (concept mastery). The data were analyzed by using paired sample t-test. The research results showed that there was an improvement in problem-solving skill from 40.68% to 74.77% and concept mastery from 0.48% to 0.72%. The result of the t-test indicated that the value of $Sig_{counting} < Sig_{table}$ (0.00< 0.05); therefore, the problem-solving skills and concept mastery before and after the application of the HPIL was significantly different. The problem-solving skills required concept mastery or comprehensive knowledge from factual until metacognitive levels. Thus, teachers need to design suitable learning models to develop this basic knowledge as a foundation for developing problem-solving skills, one of them with HPIL.

Keywords: problem-solving skill, concept mastery, HPIL

INTRODUCTION

Physics is one of the subjects considered difficult by the student so far. It is a modern learning which aims at making students be able to learn effectively by using their knowledge to analyze the situation regarding physics. Besides, physics is one of the science branches trying to describe how nature works; for instance, the universal law and the relationship between physical phenomena by using mathematics language (Argaw et al., 2017). Although the formulations seem simple, the application may be a problem for the students (Leinonen, 2013a). The future challenge or the modern learning demands the students not only to master the concepts but also develop the thinking skill. One of the thinking skills that can be developed is a problem-solving skill needed in the 21st century.

The PSS is an issue highlighted in students' learning and seen as a fundamental part of science learning in the school (Gok, 2010). This is because of the close relationship of physics to the daily life in which the topic is always based on the problem (Viennot & Decamp, 2015). The PSS helps students to think, and then solve the prob-

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lems based on the relevant theory and concept. Physics problem-solving effectively demands students to identify, determine, and solve the problems using logic, literature-based, and creative thinking (Hedge & Meera, 2012). The problem-solving skills consist of some skills related to each other such as reasoning, planning, and decision making (Greiff et al., 2014). The problem-solving skills require students to connect their knowledge to solve and find a solution to a certain problem (Hafizah, 2014). A solution is needed to solve a certain problem by using knowledge, capability, and understanding got by the students (Lin, 2010). In those processes, students would get a deep understanding of the topic field, knowledge construction, new understanding and they can make a decision (Rohanum, 2013). Students' success in understanding certain problem starts with building a description of the problem to find a proper solution (Stice, 2007). This case was done by interpreting a certain problem into a simpler model by summarizing the core concepts or key concepts needed to describe a certain problem.

Connecting concepts to the phenomena need concept mastery in understanding the physics concepts. Students develop the mastery of concept when they combine the new knowledge and their own understanding (Meyer & Land, 2006). In this process, the prior knowledge often collaborates with the new knowledge to build a better concept. In the physics learning process, the mastery of concept is very significant. Anderson & Krathwohl (2016) stated that by concept mastery, the students could improve their intellectual capability, solve the problem they face and find a meaningful learning. Generally, the purpose of physics learning is to make the students have the skill to be able to improve their knowledge, have skill and attitude that can be a provision to continue their study to the higher education level and develop the knowledge and technology (BSNP, 2006)

One of the physics concepts that need a concept mastery and problem-solving skills is the topic of temperature and heat. The temperature and heat topic is close to the daily life. However, students are hard to explain the phenomena scientifically. Such a topic is one of the abstract topics in physics subject learning (Zacharia et al., 2008). The topic of temperature and heat is rich in concepts correlating each other including some parts of which understanding is overlapping (Leinonen, 2013a). For example, explaining the heat as an energy moving from a certain object to another object is a result of temperature change (Young & Freedman, 2004) and connecting two concepts namely energy and temperature. Therefore, the complete concept mastery is necessary. The students' success in mastering the concept is not about how to answer correctly and systematically but how the students understand the physical process of a certain problem (Wambugu & Changeiywo, 2008). The fact happening in the field is the learning only focuses more on the mathematics calculation than the physics concept mastery in problem-solving (Gaigher et al., 2007). When the students are low in solving the problem, they may less understand a certain topic being discussed (Minner 2010; Maloney, 1994). Therefore, a research is needed to identify the students' problem-solving skill and concept mastery on the topic of temperature and heat.

The concept mastery cannot be reached only by using traditional learning (Bass et al., 2009), thus, certain learning model supporting the student's concept mastery on the topic of temperature and heat is urgently required. In this work, one of the solutions proposed by the researcher to improve the students' problem-solving skill and concept mastery is applying the HPIL (Hints and Peer Interaction Learning) model in the learning process. The HPIL is expected to improve the problem-solving skills and concept mastery of heat since the HPIL covers a more effective learning giving hints to the students before doing an evaluation as the student activation and doing peer interaction as the student discussion with their mates to compare the students' understanding through a discussion.HPIL model is a new model developed by Leinonen et al. (2013b). In that research, HPIL was applied since the model could significantly enhance the concept mastery and qualitative problem-solving (Cheng & Ku, 2009). Thereby, this research aimed to uncover the improvement of problem-solving skills and physics concept mastery on temperature and heat topics by applying a learning model of HPIL.

METHODS

This research used a mixed method combining the quantitative and qualitative. The research design used in this research was embedded experimental model (Cresswell & Clark, 2013). The population used in this research was one of the Senior High Schools in Malang City while the sample was 22 students. The sample selection was performed by simple random sampling technique; lottery. The topic taught was temperature and heat. The instruments were in the form of test items consisting of 25 numbers including five numbers of essay item for the problem-solving skills and 20 numbers of reasoning multiple choices items for the concept mastery. This research was conducted to measure the problem-solving skills. The problem-solving skills consist of four indicators; identifying the problem, planning the problem-solving, applying the problem-solving, and checking the adapted answer (Cukurova et al., 2016). The data of problem-solving skill were measured by using an essay test based on a rubric of the heat and its move. The data analysis comprised quantitative and qualitative analysis. The quantitative analysis included the normality test, hypothesis test, N-gain, D-Effect Size. The normality test used Kolmogorov Smirnov while the hypothesis test employed the paired sample-test. The qualitative data analysis obtained from the data processing of the students' concept mastery by analyzing the reason written by the students when they finished the pre-test and post-test.

RESULTS AND DISCUSSION

The purpose of this study was to improve the problem-solving skills and physics concept mastery by implementing the HPIL model. The steps of the learning included pre-introduction, introduction, key activity, and closing activity. The core activity consisted of individual working, hints and peer interaction. The description of problem-solving skills data and the description of problem-solving skills data are presented in Table 1.

Table 1. The Description of Problem-Solving Skills

Statistical Description	Pre-Test	Post-Test
The number of students	22	22
Mean	40.68	74.77
Maximum score	50	95
Minimum score	30	60

Based on Table 1, the statistical description of the students' pre-test mean on problem-solving skills in the experiment class was 40.68 with the total number of the student was 22 and the students' post-test mean on problem-solving skills in the experiment class was 74.77 with the total number of the student was 22. Based on the description of problem-solving skills data, the comparison of the mean of problem-solving skills in the pre-test and post-test is shown in the following Figure 2.

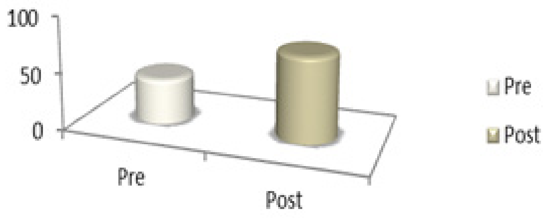

Figure 2. The Comparison of Problem-Solving Skills Average

Based on Figure 2, there was a difference of the students' mean of problem-solving skills in the pre-test and post-test using the HPIL model. From the figure, we could conclude that the mean score of problem-solving skills using the HPIL model was higher than before using the HPIL model. The data of physics concept mastery are presented in Table 2.

Table 2. The Description of Concept Mastery Data

Understanding Degree	Average (%)	
	Pre-Test	Post-Test
Understanding the concept	0.48	0.72
Misconception	0.18	0.08
Not understand	0.33	0.2

Based on Table 2, the average score of students mastering the concept increased from 0.48 to 0.72, the average of students' misconception decreased from 0.18 to 0.08, while the average of students who did not understand the concept decreased from 0.33 to 0.2 after treatment.

Going on the description of concept mastery data, the comparison of the average of concept mastery in pre-test and post-test is shown in Figure 3.

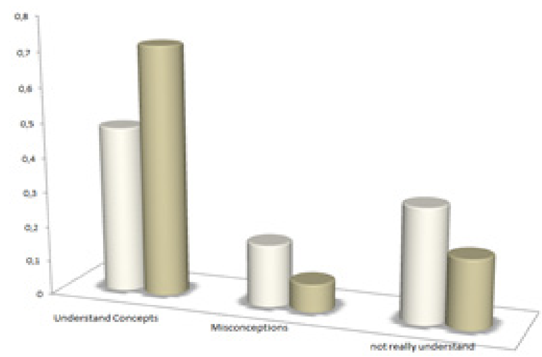

Figure 3. The Comparison of Concept Mastery Average

Based on Figure 3, there was a difference of the average of understanding the concept, misconception, and do not understand the concept at the pre-test (before using HPIL) and post-test (after using HPIL). From the figure above, we could draw a conclusion that the mean score of concept mastery using the HPIL model was higher than before using the HPIL model. Before doing the hypothesis test, the analysis of pre-requirement test was done first in the form of a hypothesis test. The normality test results of problem-solving skills and concept mastery were distributed normally. The results of the hypothesis test of this research are presented in Table 3.

Table 3.The Result of Hypothesis Test of Problem-Solving Skill

Pair Pre and Post	
$Sig_{counting}$	0.00
Sig_{table}	0.05

Based on the analysis results, the problem-solving skills showed $Sig_{counting} < Sig_{table}$ (0.00< 0.05), therefore, we could conclude that H_0 was rejected and H_1 was accepted. This showed that the problem-solving skills increased by using the HPIL model.

Meanwhile, the analysis of N-gain score used to know the increase in pre-test and post-test was in the low category with the score of 0.34. To know the strength difference, the pre-test and post-test were in the moderate effect category with the score of 0.70. Subsequently, the hypothesis test data of concept mastery are presented in Table 4.

Table 4.The Results of Hypothesis Test of Concept Mastery

Pair Pre and Post	
$Sig_{counting}$	0.00
Sig_{table}	0.05

Based on the analysis result, the concept mastery showed Sigcounting<Sigtable (0.00< 0.05), thus, we could conclude that the H0 was rejected and H1 was accepted. This case showed that the concept mastery increased by using the HPIL model. Meanwhile, the analysis of N-gain value used to know the increase in pre-test and post-test was in the low category with the score of 0.23. To know the stregth difference, the pre-test and post-test were in the moderate effect category with the score of 0.26.

The results showed an enhancement of the problem-solving skills after using the HPIL model proven by the increase of pre-test and post-test mean from 40.68 to 74.77. The increase in the problem-solving skills in this research was categorized as low since the score of N-gain was 0.34. The problem-solving skills of pre-test and post-test were based on the N-gain score, which was normalized at the moderate category having the score of 0.34. The previous research also proved that the improvement of the students' problem-solving skills was in a low category because the students found it difficult in solving the physics problems (Pol et al., 2008).

The research results by Tambychik & Meerah (2010) pointed out that 80% of the participants had troubles in solving mathematical problems compared to verbal problems. This was because most participants feel bored in completing tasks, in addition to requiring a lot of knowledge, work procedures, and require additional time in thinking. Furthermore, Snetinova & Koupilova (2012) revealed that many students had low problem-solving skills, which resulted in difficulties in solving physical problems. These occurred due to the lack of essential knowledge in solving physical problems, including declarative knowledge (facts & concepts), procedural knowledge (how to use facts and concepts in methods/procedures), and strategic knowledge (needed to regulate the process of new problem solving).

The description of the students' problem-solving skills improvement from the pretest to posttest is described through the students' answer transcripted as follows. The example of question number 1.

Andi experimented by heating water (A) and cooking oil (B), where mass A and B were the same. A few minutes later, it turned out that the temperature of cooking oil increased faster than water.

a. Why does the temperature of cooking oil increase faster?

b. Write the relationship between the specific heat and the increase in temperature.

Student Answers (Pre-Test)

A. The temperature of the oil is faster heat because the specific heat is greater than water so the heat needed is also large.

b. Specific heat has a relationship; if the temperature is slow then the specific heat gets smaller.

Student Answers (Post-Test)

a. Oil heat faster than water because oil has a smaller specific heat. The smaller the specific heat, the faster the heat as it requires less heat, while the greater the specific heat, the slower the heat since the heat needed must also be more.

b. The greater the specific heat, the slower the increasing temperature, on the contrary, the smaller the specific heat, the faster the increasing temperature. Thus, the relationship between increasing type of heat and temperature is inversely proportional ($c \sim 1/\Delta T$).

The students' answers during the pretest were categorized at the level 2 since they could only determine problems known and asked but were not in accordance with the concept, however, they could rewrite the problem in a different form. After experiencing learning with the HPIL model, the students' answers changed drastically or experienced a significant increase to the level 4. At this level, they could determine problems known and asked based on the concepts and rewrite problems in different forms (mathematical, graphs and diagrams)

Meanwhile, the calculation of the different strength between the pre-test and post-test employed the D-Effect Size. On the basis of this research, we could see that the strength difference between the pre-test and post-test was in the category of 'strong enough' effect, having the score of 0.70. This was due to the significant difference in the students' scores during the pre-test and post-test. Another factor causing the problem was the limited time in doing pre-test and post-test. From the five questions given, the students were more skillful in doing the calculation item than the concept item. The analysis results stated that the HPIL learning model could improve the students' problem-solving skills proven by the analysis of sigcounting<sigtable (0.00 < 0.05). The results of this research were similar to the previous research reporting that the HPIL model could improve the qualitative problem-solving skill and concept mastery significantly (Leinonen et al., 2013b).

The improvement of HPIL model is a new development of learning developed by Risto Leinonen (2013a). In his research entitled overcoming students misconceptions concerning thermal physics with the aid of hints and peer interaction learning during lecture course', there are some phases of HPIL. The first phase was individual working. In this step, the students did the diagnostic test individually. This phase was used to encourage the students to implement the topic that has been taught and the homework session. After that, a hints phase was planned to state whether the hints related to the physical topic can improve the students' concept mastery. In the hints phase, the teacher gave a guide in the form of concept and formulation. The last was Peer Interaction phase; the students were asked to compare their answers to their partner and discuss. From such activities, there will be an interaction between the peers in sharing the idea based on the answer of everybody so that there will be an interaction to build a new knowledge and students' problem-solving process (Tolmie et al., 2010). Therefore, basically, in the learning process, the students in the group are expected to be heterogeneous meaning that the students having much more knowledge can share their knowledge with the ones having a little knowledge.

The results of concept mastery data were obtained from the reasoning multiple choices items. The data analysis result showed that the students' concept mastery increased after they were given treatment. From the multiple choices test given in pre-test and post-test, the students who understood the concept increased from 0.48 to 0.72, the students who underwent misconception decreased from 0.18 to 0.08, and the students who did not understand the concept decreased from 0.33 to 0.2. These cases showed that the level of concept mastery increased after giving the treatment. The HPIL model also can improve the student's concept of mastery. This case is proven by the analysis of sigcounting<sigtable (0.00 < 0.05). The results of this research were similar to the previous research stating that HPIL can improve the qualitative problem-solving skill and the concept mastery significantly (Leinonen et al., 2013b). The increase in the problem mastery in pre-test and post-test based on the normalized N-gain score was at a low category. The improvement of the problem mastery in pre-test and post-test based on the normalized N-gain score was at the low category with the range of 0.23; this research result was similar to the previous research reporting that the improvement of students' problem-solving skill was at a low category (Pol et al., 2008). Meanwhile, to measure the difference strength between pre-test and post-test was by using D-Effect Size calculation. From this research, we found that the difference strength in pre-test and post-test was categorized as the moderate effect with the range of 0.26. This case was because the difference between pre-test and post-test scores increased insignificantly. Another factor was time management in doing pre-test and post-test. The goal of the students' concept mastery improvement was to make the students have better knowledge when they are in the higher level of the carrier and increase the students' critical thinking skill and creative thinking (Saprudin et al., 2017).

CONCLUSION

Based on the discussion explained before, we can draw a conclusion that there was an increase in students' problem-solving and concept mastery in class X of Senior High School in Malang on the topic of temperature and heat after the students were taught by using HPIL model. The hypothesis test results on both variables also indicated that $sig_{counting} < sig_{table}$ (0.00 < 0.05). It means that there was a significant difference between the pretest and posttest through the application of the HPIL model to problem solving skills and physics concept mastery. Thereby, the HPIL can be recommended to improve the students' problem-solving skills and physics concept mastery. The further research is expected to see the other aspects such as the students' conceptual change (mental model), creativity and critical thinking related to physics learning by using the HPIL model.

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