Building students’ problem-solving skill in the concept of temperature and expansion through phenomenon-based experiential learning

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Abstract. This research is aimed to describe students’ problem-solving skill in phenomenon-based experiential learning especially in the subtopics of temperature and expansion. The problem-solving skill is one of the vital skills in physics learning that should be applied in measuring students’ understanding level. This research used a mixed-method approach with research design of an embedded experimental model for 32 eleventh graders of State Senior High Schools in Malang, East Java, Indonesia. The data were collected by pretest and posttest using tests and interview. The result shows that there is an improvement of students’ problem-solving skill after being taught by using phenomenon-based experiential learning. The calculation result of the N-Gain score showed the improvement of students’ problem-solving skill on a moderate category and the calculation result of d-Cohen effects size in on strong category. Meanwhile, the result of the qualitative calculation showed that students’ problem-solving skill is improved from beginner category to expert category that is 62.5%. The students’ problem-solving skill should be intensively trained by using contextual scientific problems in daily life.

1. Introduction
The topics of temperature and expansion are interesting to be studied in the school-student level. Since this concept has been presented in the question of PISA 2015 Scientific benchmark [1]. The concept of temperature and expansion are also abstract so that it causes many misconceptions to students especially on the subtopic of expansion [2]. One of the misconceptions undergone by most of the students is they have less attention to the difference of expansion coefficient of a particular object with two different types of material [3]. Another misconception related to expansion is when an object with a hole is exposed to the heat, the diameter of the hole will decrease. The understanding of the concept on the subtopics of temperature and expansion is a significant aspect of a problem-solving skill so that it is unsurprising if the topic of expansion is considered vital in the science curriculum for all educational levels [2].

Problem-solving skill is one of the essential skills in physics learning and be the focus of 21st century learning [4]. In the context of big-scale assessment such as PISA, problem-solving skill can be defined as an inter-discipline skill that applies cognitive skills such as scientific reasoning and high-order thinking [5]. Many pieces of research that have been conducted related to problem-solving and the result shows that the students are still in the low category [6]. Students’ problem-solving is categorized into two types namely expert and beginner [7]. When solving a problem, the expert students start by describing the problem using a qualitative explanation to plan the solution and then continue by using a quantitative analysis through a mathematic equation [8]. Meanwhile, the beginner
students begin by using the available mathematic equation [9] without considering the relevant concept to the problems that will be solved and then the plug and chug are done to obtain the solution [10]. The learning development of students’ problem-solving skill can be carried out by applying a learning strategy based on some principles in the 21st century that is the relevant learning needed in the real or contextual life [11]. One of the learning strategies that is suitable for such a principle is experiential learning [12].

Experiential learning is a process of building knowledge based on the experience and context of real-life involving students in doing the task, solving the problem, or handling a project through feedback, reinforcing the concept, and applying the knowledge in a new situation [13,14]. The constructivist theory believes that students can interpret information to their minds only in the context of the experience that can be observed and explored [15]. To review the experience that can be observed and explored needs a learning that is oriented to real-life; one of the ways is through phenomena [16]. Phenomenon-based learning plays a central role in developing transversal competency that connects many fields of knowledge and skill-oriented to real life [17]. Phenomenon-based learning can be undertaken through the students’ experience by orienting to real life [16]. Based on that case, in order to facilitate students on learning based on experience-oriented to real-life phenomena, the combination of both kinds of learning is needed. Phenomenon-based experiential learning is a solution to such a problem. This research is aimed to know the effect of phenomenon-based experiential learning to students’ problem-solving skill, especially in the subtopic of expansion.

2. Methods
This study used a mixed-method approach with an embedded experimental model that describe students’ answer with different types of data namely quantitative and qualitative data. This research is focused on description of students’ problem-solving skill in the subtopic of expansion. The participants in this study consisted of 32 eleventh graders of State Senior High Schools in Malang, East Java, Indonesia, who took temperature and heat materials. The sampling technique used was purposive sampling. The research instrument used was a test on students’ problem-solving skill with Cronbach alpha Reliability value of 0.82. The test consisted of 2 questions of an essay. The categorization of students’ scores was based on the assessment from Chi (1982) namely expert and beginner. The data analysis was carried out with qualitative analysis to describe the students’ problem-solving skill for subtopic of expansion which was analyzed by using coding and data reduction; moreover, quantitative analysis was analyzed by Wilcoxon Signed Ranks Test, effect size test, and N-Gain test. This research applied phenomenon-based experiential learning in the learning process which stages presented in Figure 1.

| Concrete Experience | In this stage, a teacher proposes questions and gives problems to students at the beginning of learning by presenting interesting phenomena in real-life contexts based on students’ experiences of real problematic situations to build students’ concept. |
| Reflection Observation | In this stage, students actively observe the presented phenomena and try to solve the problems and understand them through a particular theory, concept, or scientific procedure. |
| Abstract Conceptualization | In this stage, students start to learn how to make an abstraction or “theory” of the observed phenomena. In this step, students are expected to be able to make some general rules of various events; although, they look different, they have a similar principle of the rule. |
| Active Experimentation | In this stage, students can apply a particular concept of theory into real situation obtained from the observation of those phenomena. |

Figure 1. Syntax of Phenomenon-based Experiential Learning
3. Results and Discussion
The result of data analysis of students’ problem-solving skill in subtopic of expansion showed the average scores of pre-test and post-test of the students were 29.30 and 60.94. Meanwhile, the standard deviation scores of students’ pre-test and post-test were 10.34 and 23.92. Based on the obtained results, students’ problem-solving skill in subtopic of expansion improved after they were taught using phenomenon-based experiential learning. The enhancement of students’ problem-solving skill can also be seen from the average score of N-Gain which was 0.45, and was categorized as moderate. Phenomenon-based experiential learning significantly influences problem-solving skill shown by the effect size score of 1.73.

Besides, the Wilcoxon Signed Rank Test with Asymp. Sig. (2-tailed) 0.000 proved that phenomenon-based experiential learning affected the improvement of students’ problem-solving skill.

The improvement of students’ problem-solving skill for subtopic of expansion who were taught using phenomenon-based experiential learning can be seen from the improvement on the students’ pre-test and post-test scores as presented in Figure 2.

![Figure 2. Students’ Problem-Solving Skill on Pre-Test and Post-Test](image)

Most of students’ problem-solving skill is improved on the subtopic of expansion. This research’s result is supported by some previous researches which were reporting about phenomenon-based experiential learning that can enhance students’ problem-solving skill [18,19]. The learning process that is provided on the oriented experiences to the real phenomena could train students’ problem-solving skill [20]. The study conducted by Moore (2016) also shows that experienced-based learning could help students in solving the problems related to temperature and heat through real context [21]. Phenomenon-based experiential learning is suitable for teachers’ and students’ needs in the 21st century that results in meaningful learning by involving students in solving the problems relevant to the real phenomena [22]. Experience can create students’ initial scheme of a specific concept by combining the new knowledge perceived with the primary scheme stored in the long-term memory obtained from experience [14]. The unstructured results of the interview with some students revealed that most of the students were more enthusiastic about learning using phenomenon-based experiential learning. Phenomenon-based experiential learning in the learning field significantly impacted the whole students’ success in the school [23]. This case happened since phenomenon-based experiential learning could assist the students especially in understanding the concept via investigation coming from the phenomenon occurring in real life [24]. Phenomenon-based experiential learning uses contextual phenomena as a catalyst to help students in developing the capacity and skill in the learning process [25]. This case shows that physics problem-solving skill could be improved by using an approach of phenomena related to daily life.

After applying phenomenon-based experiential learning, most of students’ problem-solving skill enhanced from beginner to expert. The percentage of the students’ problem-solving skill at each level after they were taught using phenomenon-based experiential learning is presented in Figure 3.
Figure 3. The Percentage of Students’ Problem-Solving Skill for Each Category

Students who have problem-solving skill are categorized as a beginner because of the students’ low ability in understanding the concept of physics and doing as well as transferring knowledge [7]. Less understanding of problems is the main obstacle in problem-solving skill area [26]. Besides, most of students are difficult in identifying problem [7]. Many researches on problem-solving skill revealed poorly result that students were still on beginner category [6]. The results of an unstructured interview undertaken to some students showed that the students on beginner category had limited knowledge to the definition and they were unfamiliar with some terms of physics variables (i.e. expansion) in the question. This case is in line with the research conducted by Staggers & Norcio (1993) that indicated low problem-solving skill is influenced, for example, by cognitive skill and problem-solving representation skill which were done by students [27]. Besides, the students also tended to understand the problems based on the quantities stated in the questions, and then matched them with the containing concept. Improper initial problem analysis will make students’ difficulty in determining a strategy to get a solution [9].

The students are categorized expert on problem-solving skill because they have had sufficient knowledge and have been skillful in doing the procedure and transferring the owned knowledge from a previous problem to a new problem. Solving a new problem can be easier when students can build experience with other problems that have been successfully solved [28]. Based on the results of the interview on the expert problem-solving skill students, the strategy is used when they start to describe the information qualitatively and use that information to determine the right strategy to solve the problems before writing the mathematical formulation. This case is in line with the criteria of problem-solving skill on expert category which states that the students begin to solve the problems by describing qualitatively [29,30]. The initial description can help students to determine the problem-solving strategy [31]. The examples of beginner and expert students’ answer after undergoing phenomenon-based experiential learning for the concept of temperature and expansion are shown in Table 1.

Table 1. Example of the Answer of Beginner and Expert Students

| Question                                                                 | Beginner                                                                 | Students’ Answers                                                                 |
|--------------------------------------------------------------------------|--------------------------------------------------------------------------|----------------------------------------------------------------------------------|
| A seller has trouble to open a bottle cap made from aluminum attached to a bottle. The seller finally immerses the bottle into hot water for a few minute. He then tries to open the bottle again and finds that the bottle is opened. | The size of the bottle cap will increase so that it will be easily removed from the bottle. | Since the expansion coefficient of the bottle cap (aluminum) is higher than the bottle (glass) so that when the cap (aluminum) is immersed into the hot water (high temperature), the cap will expand faster compared to the bottle so that the cap can be easily removed from the bottle. This case matches the equation of volume expansion of an object $\Delta V = V_0\gamma\Delta T$ in which the rise of the volume on a particular object is in line with its volume expansion coefficient. |
The students on beginner problem-solving skill tend to solve the problems based on the experience and cannot be able to connect between the given problems with the concept of temperature and expansion. The reason is because the students’ skill are less developed when they implement the concept into the problem-solving process so that they face difficulty in solving more complex problems. Based on the result of interview, it shows that some beginning-students are unfamiliar with the word “expansion” so that they tend to use non-scientific words. Besides, the students also consider that the bottle cap can be removed from the bottle. Meanwhile, the students who have the problem-solving skill as expert tend to categorize the problems based on physics principles that are relevant and solve the problems regularly [29,32]. The result of the interview to the expert-students indicates that students’ understanding on the concept of expansion is considered good. This case is proven by the students who can explain that the bottle cap and bottle similarly encounter an expansion, but the bottle cap expands faster than the bottle since the expansion coefficient of the bottle cap is bigger than the bottle.

4. Conclusion
The students’ problem-solving skill for the topic of expansion improved after they were taught using phenomenon-based experiential learning. About 62.5% of students’ problem-solving skill is improved from beginner to expert category. The data shows that when the students are given a specific problem, most of them can identify the factors of the given problems and can build a conceptual scheme to solve the problem. This study is recommended for further researches that want to explore problem-solving skill deeply on the topic of temperature and heat especially on misconception undergone by beginner students when they solve the problems.

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