MEASUREMENT OF PHYSICS PROBLEM-SOLVING SKILLS IN FEMALE AND MALE STUDENTS BY PHYSTEPROSS

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ABSTRACT

Problem-solving skills in physics (PSSP) are essential in 21st-century life, and it is no exception for senior high school students; therefore, assessment has to be done in the senior high school. The study aimed at (1) describing students' PSSP and (2) comparing the PSSP between female and male students. A total of 466 students were selected, 290 female and 176 male, as research participants selected by stratified random sampling from low, moderate, and high scores of the national physics examination. To measure the students' problem-solving skill levels, the PhysTeProSS test was administered. The data were polytomous in four categories and were analyzed by the partial credit model (PCM). The results showed that the students' level of PSSP was dominantly at the moderate type (48.28%) and the high and very high level are at 27.43 %. In other words, female students showed a higher level of PSSP than male students.

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INTRODUCTION

In this present 21st century, the world of science and technology has experienced fast development in various facets of life. In light of the Advancement in the global era, the quality of human resources, directly and indirectly, becomes a crucial need for facing the challenges. The variety of human resources is obtained from the quality of educational outcomes such as efforts to elevate educational excellence, which become an essential factor in determining the progress and success of national development.

Survey results from science literacy of the Programme for International Students Assessment (PISA) version show that Indonesia occupied the 40th rank in 2009 and this position fell to the 64th out of the 65 countries in 2012; an indication that education in Indonesia faces a severe problem (Kemendikbud & OECD, 2013). In another view, a 2011 survey by Trends in International Mathematics and Science Study (TIMSS) reveals that the Indonesian average grade of the science competencies was 406 of the world average of 500. This average grade was 27-points lower than the 2007 figure; which is 427 out of the world's 500 (TIMSS & PIRLS, 2011). These surveys show a decrease in the competitiveness qua-

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lity of Indonesian school graduates in the world. Improvement of the quality of education in Indonesia has become a focus of the Government's efforts by conducting reformative actions in the curriculum, learning processes, and evaluation to prepare the students in facing the challenges of the 21st century. It is, therefore, true that changes have been conducted in the educational goals so that students will acquire competencies and life skills.

Physics is part of science that underlies the advanced science and technology. Collette & Chiappetta (1984) stated that physics is a way of thinking, a way of investigating, a body of knowledge, and science and its interactions with technology and society. This means that physics must be understood as a way of thinking, a form of doing research, and a bind of knowledge and science in its interaction with technology and society's life. It is therefore understood that physics becomes an essential need in school learning.

An instructional process is undoubtedly an effort to guide learners to acquire meaningful learning. One of the ways to obtain meaningful learning is problem-solving. If the learners are given continuous practice in problem-solving, it is somewhat possible that they will acquire the skills to collect information, analyze it, and re-evaluate what they have obtained (Helaiya, 2010). Moreover, Ollerton (Eseryel et al., 2014) explained that problem-solving is essential in autonomous learnings and helps add meaning to what is learned. Problem-solving skills can help students in acquiring more effective thinking skills. In short, the primary urgency of this research is to increase the students' ability to work on problems that form problem-solving in physics subjects.

Problem-Solving skill is one's sufficient capability to elevate learning achievement and implant abilities to adapt to the situation meaningfully, whereby the students become more active learners (Robbins & DeCenzo, 2005). Dede (2010) confirmed that students must have the abilities to respond to the challenges of the 21st century, and one of these abilities is problem-solving. Problem-solving is the most critical and comprehensive challenge of the 21st century (Maulana et al., 2015) in which advanced problem-solving skills are needed in education. It is undoubtedly true that problem-solving is a component that needs to be developed. A set of materials will give an important concept, and learners can exercise their problem-solving skills, which, in turn, will increase their knowledge.

Nevertheless, it is a fact that, in problem-solving, students do not seem to have adequate knowledge and skills to convert the qualitative to the quantitative. They do not seem to have the competences to experience different conditions. A cause of ineffective problem solving is that the students do not seem to understand the core of the process of the assigned problem solving (Dinica et al., 2014). A different solution in the problem-solving practices is one that translates qualitative matters into quantitative (Eggen et al., 2004).

Physics is one of the vital school subjects in the era of informational technology (IT) (Madul & Orji, 2015). The contribution of physics to society in the IT era is real (Eraikhuemen & Ogumogu, 2014). The physics school subject is demanded to help students to solve complex problems using their knowledge and understanding in real situations. In essence, physics learning requires learners to develop their competencies in problem-solving.

On the other side, problem-solving skills are needed as one of the tools in studying physics. The problem-solving skills are functional for explaining, predicting, and elaborating science (De Cock, 2012; Dinica et al., 2014). Problem-solving skills are at the analysis and evaluation levels; however, most students use competencies at the primary level that has been memorized before (Walker & Leary, 2009). The students tend to see their knowledge more as memorization than experience. This has caused them failing to use their practical skills in their learning. This makes the students do not want to learn about their affective abilities. This fact is supported by previous studied in different school levels, such as the junior high (Wartono et al., 2018) and the senior high (Kikuchi, 2009). Furthermore, these studies show that test-item problems heavily rely on recall skills and base concepts.

Problem-solving will effectively work if students can analyze and evaluate the given problems. A problem-solving competency is one for which a person can find a solution to the problem effectively and accurately. It is a skill in thinking for alternatives for the possible solutions to the problem. It is in line with the thinking experiences of a person that can be categorized as a cognitive skill through experiences. It's a multi-dimensional skill—taking a look at the list of skills involved, according to critical thinking guru, Richard Paul. As a skill, it's something you get better at, gradually, with practices (McPeck, 2016). The cognitive thinking skills must be parallel with the theory, while maturity and readiness for cognitive development must be in line with the personal and experiential development of the

person (Piaget, 2005). Availability of the thinking skills makes the students able to acquire learning through experiences.

Changes in learning that are merely based on fundamental concepts tend to lead students to have teacher-oriented competences. Assessment is needed to measure learning results in a better way. The evaluation will give the students readiness and guides them in determining changes (Gronlund, 1998). A need is felt on the development of an instrument that will be able to produce test items that are in line with the problem-solving skills of the students. It is, therefore, reasonable to develop an evaluation instrument that will support problem-solving skills.

Assessment is part of evaluation which deals with measurement. Results of the assessment will give a picture of the effects of what has been done, a reward of what has been achieved in a learning process. One of the assessment type systems is a test, which is a critical component of an instructional system (Mardapi, 2008). A test must be able to measure each student's competences objectively referring back to the instructional objectives (Miedijensky & Tal, 2016). Various alternatives are available for measuring one's capabilities. A good test gives information on the student's thinking competencies based on the characteristics; a proof that genuinely measures thinking skills by the competency level of each student.

The theories of educational assessment continually change, classically, or in modern ways. One of the contemporary assessment tools that genuinely measure the students' competences is one using the response theory. Evaluation is based on phases that the students can complete. On the assumption of the partial credit model (PCM), test-item analyses are done in several stages (Istiyono et al., 2014). By way of this item-response theory, the students' thinking competencies can be identified on the problem-solving skill level.

One of the ways to know the progress of students' learning is made through evaluation. Educational evaluation is a process of gathering and analyzing information to measure the students' learning achievement (OECD, 2012). In another view, assessment is an activity of collecting data individually to give a picture of the characteristics of the individual (Mardapi, 2008). Furthermore, Black & Wiliam (2009) and Etkina, et al. (2009) elucidated that an evaluation/assessment activity is as any activity that is conducted by an instructor towards the learner in an instructional process to give feedback information to modify the instructional activities. In this light, a learning evaluation in physics is one that offers the result of the learning process in the form of a score that reflects the characteristics of each student. Evaluation is conducted by using an evaluation instrument, either oral or written.

The theoretical bases to be used in educational evaluation cover the classical and modern assessment theories. In the more conventional methods, scoring of the test is done on the correct responses. Scoring is done in every step, and individual scores are summed up to become raw scores. This scoring model is incomplete since the level of difficulty of each step is not accounted for.

The multiple-choice test is commonly used for its several conveniences. These are, among others: (1) the test material represents the instructional contents; (2) students' responses can be graded fast and efficiently; (3) the correct/wrong answer adds to the test objectivity (Sudjana, 1990). Meanwhile, one of the shortcomings of the model is the possibility that a student guesses the response so that the student's thinking scheme cannot be seen clearly. It is why a test is needed that can minimize this shortcoming. A multiple-choice test with explanations for the choices is one alternative.

METHODS

The research procedure covered: 1) selection of respondents, 2) test, and 3) data analysis. The respondents of the test were students of Grade XI from three senior high schools in Bantul Regency labelled as State Senior High School (SSHS) A, SSHS B, and SSHS C. The sample size covered 466 students, 176 male, and 290 female. Sampling was done by a stratified random sampling technique using the low, moderate, and high scores of the Physics National Examination the criteria.

The instrument to be used for the testing was the PhysTeProSS. It was a multiple-choice test with five options divided into two sets, Set A and Set B, covering the subject topics of elasticity, static fluid, temperature and calorie, and optical tools. Each of the test set consisted of 52 items with 8 anchor items. ThePhysTeProSS was validated by expert judgment (Aiken indexes for all the questions ranged from 0.8 to 1.00) which resulted in evidence for construct validity in the form of a fit on the partial credit model (PCM), based on the polytomous data with four categories (INFIT MNSQ, ranging from 0.99 to 1.03. The reliability estimate fulfilled the requirement

(reliability coefficient = 0.79), and the item readability level was rated at the "good" category (-0.95 to 1.0) (Nadapdap & Istiyono, 2017).

The test aministration in the three senior high schools took two class-period hours using the Set A and Set B tests with a seating arrangement of the front, back, right, and left so that the students got other seats following the A and B test sets. This was an attempt to minimize frauds. The test was supervised by each class teacher so that the students did the test seriously.

The data analyses of the study included: 1) determining the problem-solving skills, 2) determining the percentage of each level, and 3) comparing problem-solving skills between the male and female students.

First, to get the problem-solving skills from the students' responses on the test, the four-category polytomous data were analyzed quantitatively using the item response theory (IRT) of the 1-PL (Parameter Logistic) or partial credit model (PCM).

PCM is a development of the Rasch model of dichotomous items applied on polytomous data. The Rasch model which contained only one parameter of item location was later extended to several categories. If i is a polytomous item with the score categories of 1, 2, 3 ..., mi, then the probability of an n individual score is x on the I item which later was identified as category response function (CRF) as shown in Equation 1 (Ostini & Nering, 2006; Muraki & Bock, 1997).

$$P_{ig}(\theta) = \frac{\exp[\sum_{g=0}^{l}(\theta - b_{ig})]}{\sum_{h=0}^{m}\exp[\sum_{g=0}^{h}(\theta - b_{ig})]}$$

Notes:

$P_{ig}(\theta)$ = probability of testee with ability θ obtaining score on a category g for item i

θ = level of individual trait (individual location trait on the laten trait continuum or ability)

b_{ig} = location item parameter or level of difficulty (showing the probability of getting Score 0 and Score 1 is the same)

The second stage was working on the percentage of each level by putting it into the very low, low, moderate, high, or very high category in the face of the ideal mean and standard deviation. The measurements of the ideal mean (Mi) and the ideal standard deviation (SDi) was done using the highest and lowest scores of the research variable (Azwar, 2012).

Table 1. Score Interval for Ability Level

No	Ablity Interval	Level
1	$M_i + 1.5SB_i < \theta$	Very high
2	$M_i + 0.5SB_i < \theta \le M_i + 1.5SB_i$	High
3	$M_i - 0.5SB_i < \theta \le M_i + 0.5SB_i$	Moderate
4	$M_i - 1.5SB_i < \theta \le M_i - 0.5SB_i$	Low
5	$\theta < M_i - 1.5SB_i$	Very low

Third, separating male and female abilities to be subjected to percentage calculation and later to be compared.

RESULTS AND DISCUSSION

Distribution and Level of Problem-Solving Competencies

Results of the data analysis show that the average score of students' problem-solving skills is 0.01≈0 with a standard deviation = 1. Complete results of the skill estimation are visualized in Figure 1 as follows.
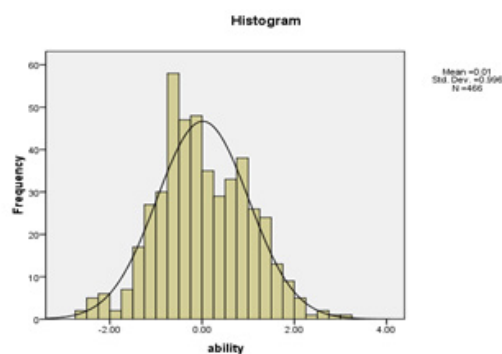

Figure 1. Distribution of PSSP

In Figure 1, it can be seen that the lowest problem-solving skill measure is at -2.68, and the highest is at 3.00. This indicated that the distribution of problem-solving abilities of students was normally distributed. Another data analysis result showed the categorization of the problem-solving skills as presented in Table 2.

Table 2. Problem-Solving Skill Levels

Level	Number	Percentage (%)
Very high	10	2.5
High	118	25.32
Moderate	225	48.28
Low	99	21.24
Very low	14	3.00

Based on Table 2, the highest percentage of the problem-solving competences was in the moderate category (48.28 %) while the smallest was at the very low group (3%). This finding could also be presented in another visual in the form of a histogram as follows.
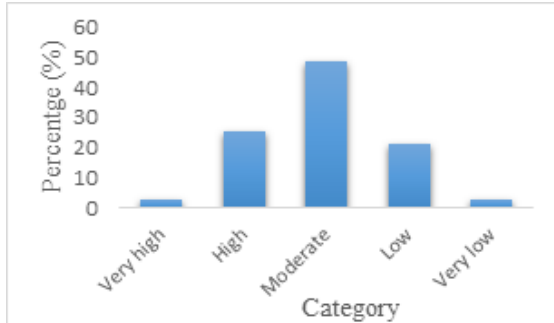

Figure 2. PSSP Category

Given the highest and lowest scores, as shown in the histogram above, there was no significant difference between the two. This can be seen from the fact that, because of the normal distribution, the students' competencies were spread on a normal curve with the majority of the data lies in the moderate category.

Distribution and Level of PSSP of Male Students and Female Students

The problem-solving skills of boys and girls indicated some differences, which can be observed in Table 3.

Table 3. Comparison of PSSP

PSSP	Female	Male
Highest	2.65	2.29
Lowest	-2.60	-3.98
Average	0	0
Standard deviation	1	1

Table 3 shows that the PSSP of female students were higher than those of the male students.
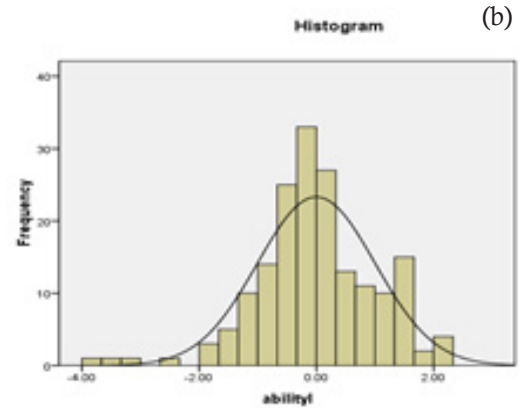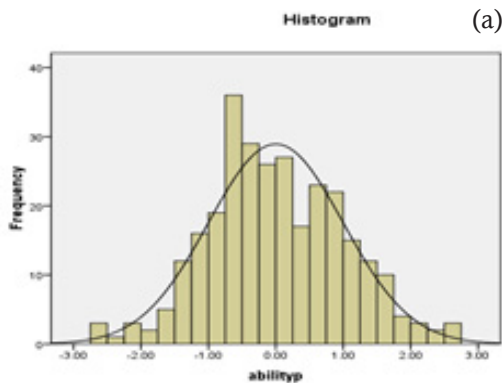

(a)

(b)

Figure 3. Comparison of the PSSP Distribution: (a) Female and (b) Male

Other than Table 3, the distribution of the students' competences in problem-solving is presented in Figure 3. The ranges of abilities in problem-solving between boys and girls were different quite significantly. The following is the visualization of this difference (Figure 4).
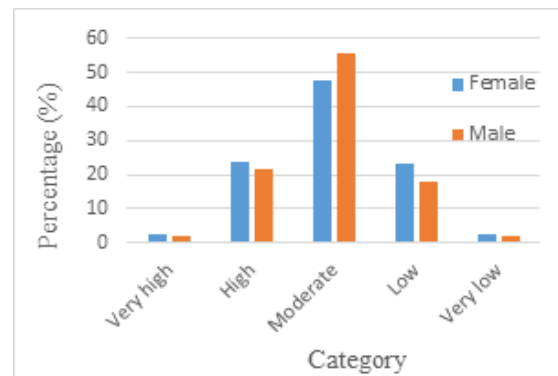

Figure 4. PSSP between Male Students and Female Students

It can also be seen from Figure 4 that both male and female students had the most frequent occurrence of problem-solving skills at the moderate category.

Distribution and Level of the PSSP

Skills in problem-solving are essential for students, especially in the subject matters of science and mathematics. The students use the skills to find a solution to a given problem in physics based on their knowledge, understanding, and abilities. It is therefore vital that evaluation in physics problem-solving skills be conducted.

The results of this study in the three senior high schools unveiled that the students' problem-solving skills were 3.00 as the highest and 2.68 as the lowest. The distribution of the competencies can be observed in Table 1.

The results of other studies showed that students' competencies in problem-solving are categorized as high; however, it takes a longer time to train students with problem-solving skills. (Sujarwanto et al., 2014). Learning, yet, is seen to be the mode in helping students improves their problem-solving skills. The study is the same as the findings of Leak et al. (2017) who explored problem-solving strategies (for example, solving problems, evaluating options, using test cases or estimates) and characteristics of successful problem solvers (for example, initiative, persistence, and motivation). Our research provides evidence of the influence that problems faced by the students take place on the strategies they use and learn.

Distribution and Category of PSSP in Female and Male Students

The research findings revealed that female students had a higher level of problem-solving skills than do male students. They had, however, the same scores for the mean and standard deviation, namely 0 and 1. This showed that the distribution had a regular curve line. The highest problem-solving skills of female students were represented by 2.65 and 2.29 for male students. This was strengthened by their lowest scores as seen in Table 3; skills for male students (-3.98) were far below those of female students (-2.60). This finding is also displayed in the graphic distribution in Figure 3. In line with the findings, Ajai & Imoko (2015) claimed that female students do better than male students in completing complex tasks like problem-solving. High levels of competency in female students are also shown by Fenemma & Leder (1990), who explained that differences in problem-solving abilities depend on gender differences in the cognitive domain and lateralization of the brain. The same results found by Close & Shiel (2009) who stated that female students tend to do better in tasks that require knowledge and skills in problem-solving. The high measure of the problem-solving abilities shows that students can identify concepts in a problem (Nurita et al., 2017) and take actions in solving problems (Bancong & Subaer, 2013).

The findings also elucidated that female students had a better distribution of competences students. Figure 4 shows significant differences in the frequency and distribution of the students' problem-solving capabilities. This is different from the findings of a previous study showing that differences are not so much influenced by gender. The success level in completing a task depends on whether or not the students identify the concepts given in the assignment, understand them, and know how to find the solution to the problem (Riantoni et al., 2017). The test pattern may also cause another discrepancy in the problem-solving competencies. For example, female students tend to find it more difficult than male students in taking a content-based test (Wilson et al. 2016).

CONCLUSION

The problem-solving skills in physics (PSSP) of senior high school students in physics were dominantly categorized as moderate (48.28%), while the high and very-high level was at 27.47 %. These findings have proven that the implementation of physics learning focusing on the ability to answer problem solving questions is considered effective. Moreover, female students tended to have a higher level of problem-solving skills in physiscs (PSSP) than male students.

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