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

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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 important in the 21st century life so that assessment is done in the senior high school. The study was aimed at (1) describing students' PSSP, and (2) comparing the PSSP between female students and male students. A total of 466 students were selected, 290 female and 176 male, as research participants by stratified random sampling from low, moderate, and high scores of the physics national 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). Results showed that students' level of PSSP was dominantly at the moderate category (48.28%) and the high and very high levels are at 27.43 %. Female students show a higher level of PSSP than do male students.

Keywords:education assessment, *problem-solving skills, physics education*

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 quality of human resources is obtained from the quality of educational outcomes such that efforts to elevate educational quality become an important factor in determining the progress and success of the nation development.

Survey results from *science literacy* of the *Programme for International Students Assessment* (PISA) version show that occupy the 40th rank in 2009 and this position fall down to the 64th out of the 65 countries in 2012; an indication that education in Indonesia faces a serious problem (Kemendikbud & OECD, 2013). In another view, a 2011 survey by *Trends in International Mathematics and Science Study* (TIMSS) shows that the Indonesian average grade of the science competencies is 406 of the world average of 500. This average grade is 27-point 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 quality of the Indonesian school graduates in the world at large. 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 in order 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 in order that students will acquire competencies and life skills.

Physics is part of science that underlies the advance science and technology. Chiappetta & Koballa (2010) state 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 way 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 important need in school learning.

An instructional process is verily an effort to guide the learner 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 not impossible that they will acquire the skills to collect information, analyze it, and re-evaluate what they have obtained (Helaiya, 2010). Ollerton (Ellison, 2009) states that problem solving is a key in autonomous learning and helps add meaning to what is learned. Problem-solving skills can help students in acquiring more effective thinking skills. From this description, it can be concluded that the main urgency of this research is to increase students' ability to work on problems that form problem solving in physics subjects.

Nevertheless, it is a fact that, in problem solving, students do not seem to have the adequate knowledge and skills to convert the qualitative to the quantitative. Students do not seem to have the competences to experience the different conditions. A cause of ineffective problem solving is that 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 (Mc. Donald, 1959). A problem-solving skill is one an effective skill to elevate learning achievement and implant abilities to adapt with the situation meaningfully whereby the students become more active learners (Noe *et al.*, 2012). One material will give a meaningful concept and the learners can exercise their problem-solving skills which, in turn, will increase their knowledge. Trilling & Fadel (2009) state 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 important and comprehensive challenge of the 21st century (Lorenz *et al.*, 2014) 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.

Physics learning is useful. Physics is one of the important school subjects in the era of informational technology (IT) (Madul & Orji, 2015). The contribution of physics to the 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 the real situations (Walsh et al, 2007). In essence, physics learning requires the learners to develop their competences 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 (Dinica *et al.*, 2014). Problem-solving skills are at the analysis and evaluation levels; but, in reality, most students use competences at the basis level that has been memorized before (Mc Bride *et al*., 2010). Students tend to see their knowledge more as memorization than experience. This has caused students to fail to use their effective skills in their learning.

This makes students do not want to learn about their affective abilities. This is supported by previous studied in different school levels such as the junior high (Wartono et al., 2018) and the senior high (Chen et al., 2004). These studies show that test-item problems heavily rely on recall skills and base concepts.

Problem solving will work effectively if students are able to analyze and evaluate the given problem. A problem-solving competency is one for which a person is able to find a solution to the problem effectively and accurately. It is a skill in thinking for alternatives of the most 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—take a look at the list of skills involved, according to critical thinking guru Richard Paul. And, as a skill, it's something you get better at, gradually, with practice (Tittle, 2011). The cognitive thinking skills must parallel with the theory that maturity and readiness for cognitive development must be in line with the personal and experiential development of the person (Piaget, 2005). Readiness of the thinking skills make the students able to acquire learning through experiences.

Changes in learning that are merely based on base concepts tend to lead students to have teacher-oriented competences. Assessment is needed to measure learning results ion a better way. Evaluation will give students readiness and guides in determining changes (Gronlund, 1976:16). 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 competences of the students. It is therefore reasonable to develop an evaluation instrument that will support thinking in relation to problem-solving competences.

Assessment is part of evaluation which deals with measurement. Results of assessment will give a picture of the results of what has been done, a reward of what has been done in the learning process. One type of assessment systems is the test which is an important component of an instructional system (Mardapi. D., 2008). A test must be able to measure each student's competences objectively referring back to the instructional objectives (Talb, 2016). Various alternatives are available for measuring one's competences. A good test gives information on the student's thinking competences based on the characteristics; a test that truly measures thinking competencies in accordance with the competency level of each student. A test is needed that really measures the students' competences in problem solving.

The theories of educational assessment continually undergo changes, classically or in modern ways. One of the modern assessment tools that truly measures 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 phases (Istiyono et al., 2014). By way of this item-response theory, students' thinking competences can be identified on the problem-solving skill level.

One of the ways to know the progress of students' learning is done through evaluation. Educational evaluation is a process of gathering and analyzing information in order to measure the students' learning achievement (Kemendikbud, 2013). In another view, assessment is an activity of gathering data individually to give a picture of the characteristics of the individual (Mardapi, 2012). In this light, a learning evaluation in physics is one that gives 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 in the form of a test. The test can be oral or written; the written test consists of items with alternative of answers to be selected.

The theoretical bases to be used in educational evaluation cover the classical and modern assessment theories. In the more classical theories, 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 not complete since the level of difficulty of each step is not accounted for.

The multiple-choice test is most 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 easily; (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 answer so that the student's thinking scheme cannot be seen clearly (Sudjana, 1990). It is why a test is needed that is able to minimize this shortcoming. A multiple-choice test with explanations for the choices is one alternative. Black & Wiliam (2009) and Etkina, et al. (2006) define an evaluation/assessment activity as any activity that is conducted by an instructor towards the learner in an instructional process to give feedback information in order to modify the instructional activities.

METHOD

The research procedure covered: 1) selection of respondents, 2) administering of the test, and 3) data analysis. The respondents of the test 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 criterion.

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 sets consisted of 52 items with 8 anchor items. ThePhysTeProSS was validated by expert judgement (Aiken indexes for all the items ranged from 0.8 to 1.00) and obtained evidence for construct validity in the form of a fit on the partial credit model (PCM), on the basis of the politomous data with four categories (INFIT MNSQ, ranging from 0.99 to 1.03. The reliability estimate fulfilled the requirement (reliability co-efficient = 0.79) and the item readability level was rated at the "good" category (-0.95 to 1.0) (Nadapdap & Istiyono, 2017).

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

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 boy students and girl students.

First, in order to get the problem-solving skills from the students' responses on the test, the four-category polytomous data were analysed 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 ..., m_i, 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: 28; Muraki & Bock,1997:16).

$$P_{ig}(\theta) = \frac{\exp[\sum_{g=0}^{l}(\theta - b_{ig})]}{\sum_{h=0}^{m}\exp[\sum_{g=0}^{h}(\theta - b_{ig})]} \quad (1)$$

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)

Second, working on the percentage of each level by putting it into the very low, low, moderate, high, or very high category in face of the ideal mean and ideal standard deviation. Finding of the ideal mean (M_i) and ideal standard deviation (SD_i) is done using the highest and lowest scores of the research variable (Azwar, 1998: 163).

Table 1.
Score Interval for Abilty Level

No	Abilty 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.

RESULT AND DISCUSSION

a. Distribution and level ofproblem-solving competences

Results of the data analyses 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:

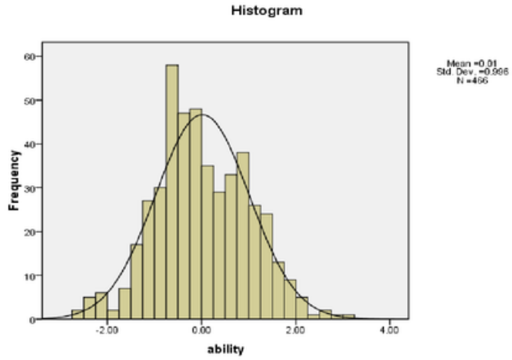


Figure 1: Distribution of PSSP

In Figure 1, it can be seen that the lowest problem-solving skill measure is at -2.68 and the highestis at 3.00. This indicates that the distribution of problem-solving abilities of students is normally distributed. Another data analysis result shows the categorization of the problem-solving skills as can be seen in Table2.

Table2: *Problem-Solving Skills*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

By Table 2, it can be shown that the highest percentage of the problem-solving competences is at the moderate category (48.28 %) while the smallest is at the very low category (3%). This finding can be presented in another visual in the form of a histogram as follows:

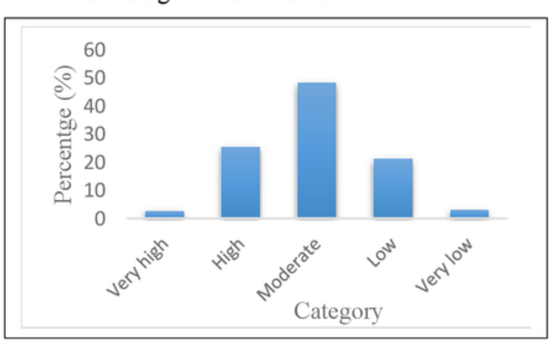


Figure 2: PSSP Category

In view of the highest and lowest scores as is shown in the histogram above, it can be said that there is no significant difference between the two. This can be seen from the fact that, in view of normal distribution, students' competences are spread on a normal curve with the majority of the data lies in the moderate category.

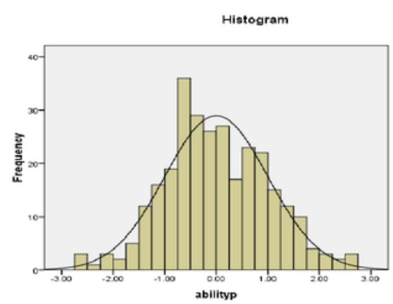
b. Distribution and level of PSSP of male students and female students

The problem-solving skills of boy students and girl students show some differences. This can be seen in Table3.

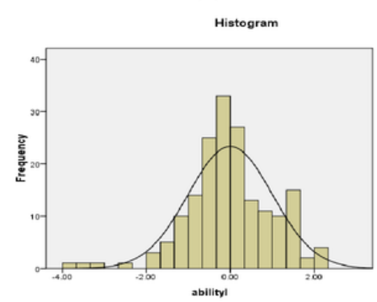
Table3: Comparison of PSSP

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 are higher than those of the male students.



(a)



(b)

Figure 3: Comparison of the PSSP distribution: (a) female and (b) male

Other than from Table 3, the distribution of the students' competences in problem solving can be seen in Figure 3. It can be explained that the ranges of abilities in problem-solving between boy students and girl students are different quite significantly. The following presents the visualization of this difference (Figure 4).

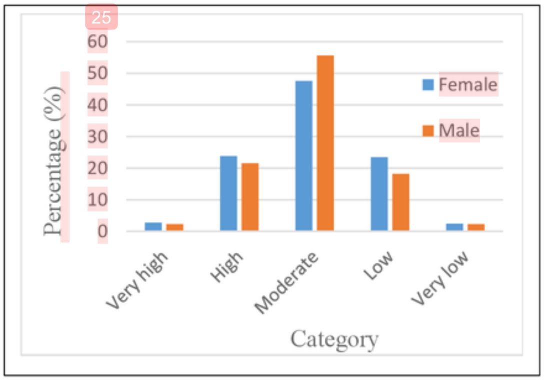


Figure 4: PSSP between Male Students and Female Students

It can also be seen from Figure 4 that both boy students and girl students have the most frequent occurrence of problem-solving skills is at the moderate category.

1. Distribution and level of the PSSP

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

Results of the study in the three senior high schools show that the students' problem-solving skills are at the score of 3.00 as the highest and 2.68 as the lowest. The distribution of the competences can be seen in Table 1.

Results of other studies show that students' competences in problem solving is categorized as high; however, it takes a longer time to train students with the problem-solving skills. (Sujarwanto et al, 2014). Learning, however, is seen to be the mode in helping students improve their problem-solving skills. The study is the same as the findings of Anne et al (2017) who explore 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 students have on the strategies they use and learn.

2. Distribution and Category of PSSP in female and male students

Research findings show that female students have a higher level of problem-solving skills than do male students. They have, however, the same scores for the mean and standard deviation, namely 0 and 1. This shows that the distribution has the normal curve line. Highest problem-solving competences of female students are represented by 2.65 and for male students 2.29. This is strengthened by their lowest scores as can be seen in Table3; competences for male students (-3.98) are far below those of female students (-2.60). This finding is also shown in the graphic distribution in Figure 3. This finding is strengthened by (Ajai & Imoko, 2015) claiming 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 Fennema & Leder (1990) which explains 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) state that female students tend to do better in tasks that require knowledge and skills in problem solving. The high measure of the problem-solving skills show that students are able to identify concepts in a problem (Nurita et al, 2017) and take actions in solving problems (Bancong & Subaer, 2013).

Findings also show that female students have a better distribution of competences than do male students. Figure 4 shows significant differences in the frequency and distribution of the students' problem-solving competences. This is different from 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 task, understand them, and know how to find the solution to the problem (Riantoni et al., 2017). Another discrepancy in the problem-solving competences may also be caused by the test pattern. For example, female students tend to find it more difficult than male students in taking a content-based test (Wilson, et al. 2016).

CONCLUSION

In view of the findings of the study, two items of conclusion can be drawn as follows.

1. The problem-solving skills in physics (PSSP) of senior high school students in physics are dominantly categorized as moderate (48.28%), while the high and very-high levelis at 27.47 %. This proves that the implementation of physics learning in the ability to answer problem solving questions is considered effective.
2. Female students tend to have a higher level of problem-solving skills in physiscs (PSSP) than do male students.

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