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The Profile of Students' Physics Problem Solving Ability in Optical Instruments

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Abstract

This research aims to analyze the profile of students' problem-solving ability in problems of optical instruments. This survey research involved 65 students class XI of MAN 3 Yogyakarta. The research instrument was in the form of 3 problem-solving questions in the form of a description. The results showed the percentage of students in the *expert* category was still relatively low at 30,7% and the students in the *novice* category were quite high at 69,3% so that students' overall physics problem-solving abilities were relatively low. In this research, some student difficulties were still found, one of which was in determining the focus of the right lens for patients with eye disorders to use glasses and determine magnification when using a magnifying glass. Efforts to implement innovative learning are needed to improve problem-solving abilities in overcoming students' physics problems.

Keywords: problem-solving ability, optical instruments, *expert-novice* criteria

INTRODUCTION

Physics has an essential role in human life as a fundamental science with characteristics that cover the scientific foundations of facts, concepts, principles, laws, postulates, theories, and methodologies of science (Mundilarto 2010; Prihatiningtyas, Prastowo & Jatmiko 2013). Various abilities in studying physics prove that physics is a complex science, so students need to optimize their abilities so that learning is well understood and correct (Nanda 2018; Mason & Singh 2016). One of the topics in physics is optics. Characteristics of optical concepts that are abstract require high thinking skills such as problem-solving to understand theories and compare them with the symptoms of daily life (Sutiadi & Nurwijayaningsih 2016; Nugraha, Kirana, Utari, Kurniasih, Nurdini, & Sholihat 2017; Nurhayati & Angraeni 2017). Students' understanding of related concepts shows that the majority of most students have constraints in physics learning, including misunderstandings stating that light comes out of the eye to objects in the process of vision (Uzun, Alev & Karal 2013). Besides, students do not understand the concepts behind mathematical equations and have difficulty in determining the magnification of shadows on the magnifying glass (Suniati, Sadia & Suhandana 2013; Rokhmah, Sunarno & Masykuri 2017). The way students perceive mathematical equations and formulas in physics will influence the understanding of physics concepts and work on physics questions correctly and precisely. Often students choose strategies that are less appropriate in solving physics problems, so students' ability to evaluate problems is still low (Sutiadi *et al.* 2016; Hamdani, Mursyid, Sirait & Etkina 2017). The other difficulties of students are to provide a scientific explanation of lens function and the formation of shadows on the lens and difficult to distinguish between convex and concave lenses (Tural 2015). The difficulties experienced by students are due to students' inability to harmonize and determine the context of the problems given with appropriate concepts and physics principles (Ding *et al.* 2011; Lin & Singh 2015; Leak *et al.* 2017). Difficulties that are still experienced by students result in students' low ability to solve a problem.

The problem-solving abilities that have been analyzed are still categorized as weak for physics learning (Hartatiek, Yudyanto & Haryoto 2017; Jua, Sarwanto & Sukarmin 2018). Research results of Riantoni *et al.* (2017) revealed that students still use a memory-based approach and rest without a clear and structured approach, only a few students can take a scientific approach to solve problems. Therefore, students are required to have excellent problem-solving skills based on relevant theories and concepts to be able to solve various physics problems (Ding *et al.* 2011; Adams & Wieman 2015). Students' problem-solving abilities can be known through five stages; namely, (1) *useful description*, (2) *physics approach*, (3) *specific application of physics*, (4) *mathematical procedure*, and (5) *logical progression*. Students' problem-solving abilities consist of *expert* and *novice* based on students' independent problem-solving alternatives (Walsh, Howard & Bowe 2007; Hull *et al.* 2013; Docktor *et al.* 2016).

Students with *novice* categories are only based on mathematical procedures without applying the right and meaningful concepts in solving problems. Students with *expert* categories are able to identify variables that influence the existing problems, and connect mathematical procedures by considering theories, concepts, laws, and principles underlying the problem, and analyzing and completing with the right concepts (Docktor & Heller 2009; Ding *et al.* 2011; Adams & Wieman 2015; Leak *et al.* 2017).

Based on the explanation above, it is crucial to analyze the profile of students' problem-solving abilities to identify the difficulties of physics learning in optical instruments. Therefore, this research aims to describe the profile and difficulties of student physics learning. The educators can prepare and design appropriate learning to train and improve students' problem-solving abilities to reduce and overcome difficulties in various physics problems.

RESEARCH METHODOLOGY

This research used a survey method conducted at MAN 3 Yogyakarta in April 2019 with a subject of 65 students consisting of 32 students class XI MIPA 3 and 33 students class XI MIPA 4. The test instrument used was in the form of three problem-solving questions in the form of a description that had been validated by two expert lecturers. The rubric assessment of student answers refers to the rubric of Docktor *et al.* (2016) with the range of scores set in this research are 0 to 4 for each indicator on each question with a maximum score of 4. Giving a score of 0 if not writing a solution, score 1 solution made wrong, score two partially a solution made containing error and partly correct, score 3 solutions made are correct, but there are still a few mistakes, and score four solutions are made right and complete. The profile of students' ability to solve a problem will be analyzed in five problem-solving indicators including (1) *useful description*, (2) *physics approach*, (3) *specific application of physics*, (4) *mathematical procedure*, and (5) *logical progression*, then grouped in the *expert* and *novice* categories, as shown in TABLE 1 (Docktor & Heller 2009; Hull *et al.* 2013; Lin & Singh 2015; Docktor *et al.* 2016).

TABLE 1. Categorizing Criteria for *Expert* and *Novice* Students

No	Indicator	Criteria	
		Expert	***Novice***
1	*Useful Description*	Describe the problem by summarizing relevant information in the symbolic form of influential variables, figures, and verbally accurately and completely.	Describe the problem by writing an influential variable that is incomplete, partly missing, or contains an error.
2	*Physics Approach*	Explain the physics approach that is useful as a solution to the problem correctly and completely	Some of the physics approaches described are not right, are still wrong, even past this step.
3	*Specific Application of Physics*	Determine the relevant equations as a solution by applying them according to the problem correctly and completely.	Only write down the general equations without applying them according to the problem, not complete, still contains errors, and do not even write them down.
4	*Mathematical Procedures*	Perform calculations according to the procedure until getting the right and complete results.	Processing and obtaining data is still inaccurate, incomplete, not even calculating at all.
5	*Logical Progression*	The settlement process used is clear, focused, and precise so that it can prove the suitability of the results obtained with the solutions used.	The settlement process used is unclear, unfocused, only rewrites the results obtained and does not connect the results to the process used as a solution

- (Docktor *et al.*, 2016)

The calculation of the score for each problem-solving solution using the formula in EQ. (1).

$$Student\ Score = \frac{\frac{Number\ of\ Scores\ for\ Each\ Question}{Number\ of Indicators}}{Number\ of\ Questions} \quad (1)$$

RESULTS AND DISCUSSION

The results of descriptive statistical analysis of the average score of students' problem-solving ability in the optical instruments show in TABLE 2.

TABLE 2. Descriptive Statistics on Students' Physics Problem-Solving Ability

Descriptive Statistics	***Value Statistics***
Number of Subjects	65
Average Score	1,78
Median	1,60
Range	0,00
Minimum Score	0,00
Maximum Score	4,00
Standard Deviation	1,28
Variance	1,65

The above calculation results show that the average score of the problem-solving ability of 65 students is 1,78 from the range of scores 0 to 4. Broadly stated, students are still in the *novice* category. It is shown from the range of the overall score of the students' answers on the three items in the form of a diagram shown in FIGURE 1.

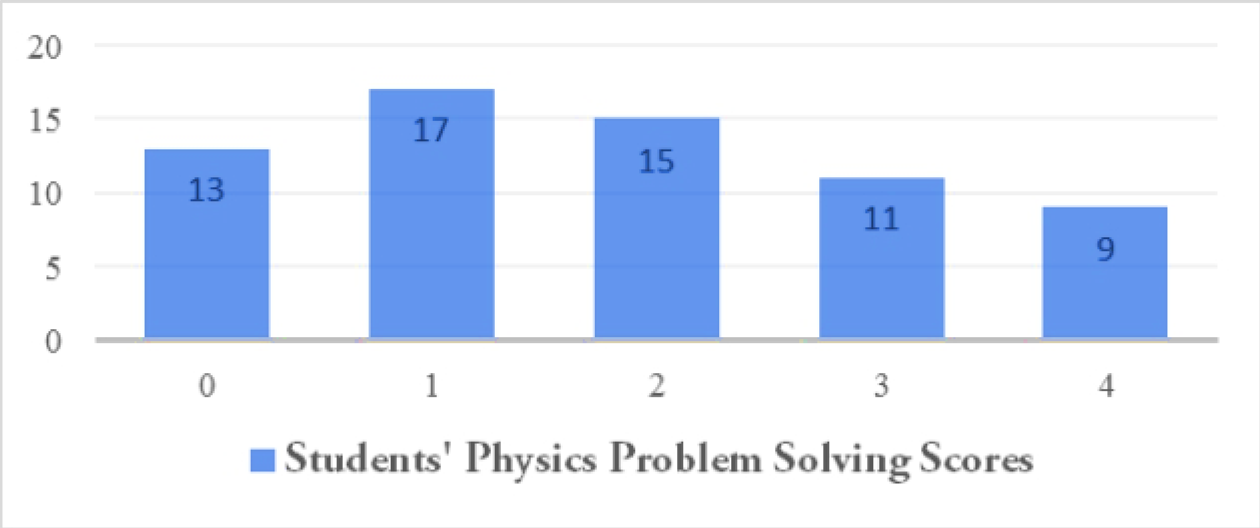

FIGURE 1. Overall Score of Students' Physics Problem Solving Ability

Students with *novice* category are on a score of 0 to 2 and the *expert* category is in a score of 3 to 4 which is determined based on the criteria of student answers to the problems in the item. The *novice* category students only write relationships that are known quantitatively and have no meaning, while the *expert* students review the problem qualitatively a have meaning. After understanding the problems listed, the *expert* student can write the right physics approach and choose the formula that will be used to solve the problem, but the *novice* student only writes the physics equation without understanding the underlying physics concepts. Solving the problem of *expert* students is stronger with mathematical strategies and evaluating the right answers, while *novice* students are less able to operate each of the data listed form the problem. Based on the overall data of the students' scores and answers, the percentage of students in the *expert* category was 30,76%, and the *novice* category was 69,23%. Analysis of the answers of students with *expert* and *novice* categories can be grouped based on each item about problem-solving, namely item 1, eyes and glasses; item 2, determines the position of the right magnifying glass; and item 3, determines the magnification of the magnifying glass. FIGURE 2 shows the results of student categorization analysis.

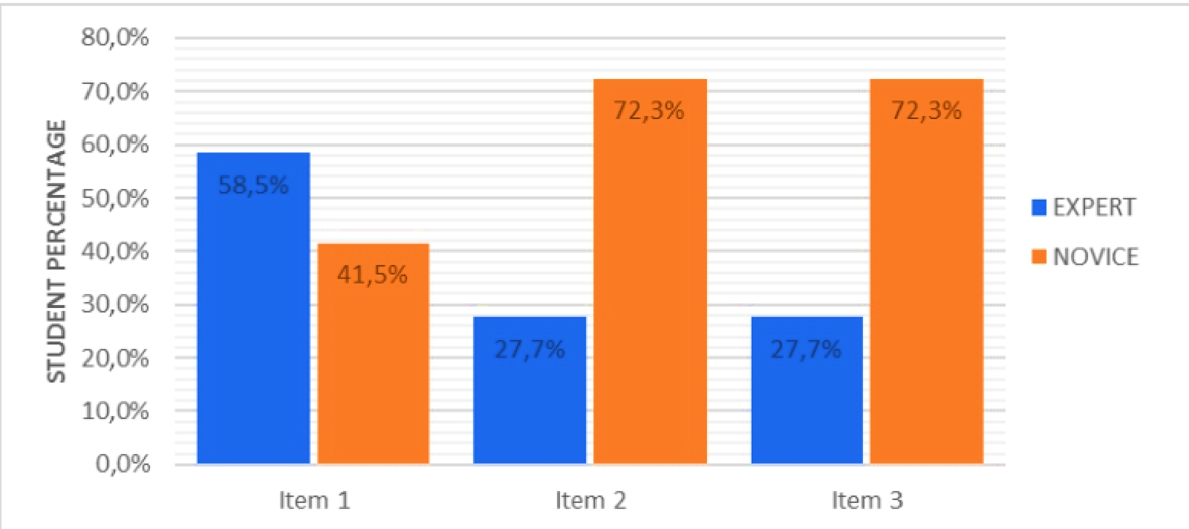

FIGURE 2. Students' Physics Problem Solving Categories in Each Item

FIGURE 2 shows the percentage of *expert* students on item 1 is higher than *novice* students, so students have been able to solve eye and glasses related problems. It is different from items two and three which get the percentage of *novice* students higher than *expert* students so that on average students have not been able to solve problems related to positioning the right magnifying glass and magnifying the magnifying glass. The results of the category analysis of *expert* and *novice* students are described based on indicators of physics problem-solving abilities in FIGURE 3.

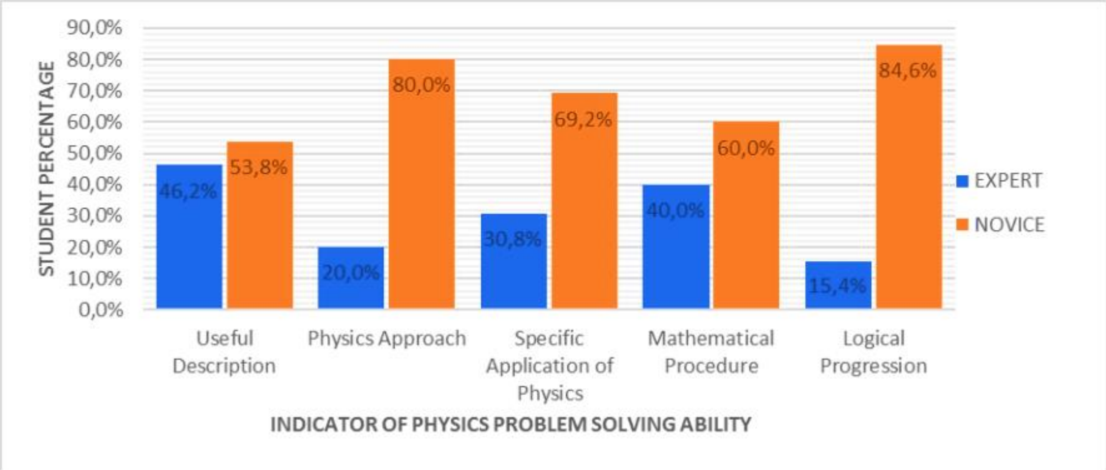

FIGURE 3. Students' Physics Problem Solving Categories in Each Indicator

Students' problem-solving abilities after learning can be known more deeply based on the analysis of criteria for the answers of the *novice* and *expert* students on the five problem-solving indicators. As for one example of a problem-solving physics as in FIGURE 4 and an example of student answers categorized as a *novice* dan *expert* as in TABLE 3.

Rendi and Tiara were classmates at MAN 3 Yogyakarta. Rendi had an eye disorder so that he was a distant vision and had a close point of 125 cm. Tiara also had eye disorders that caused her to have a distant vision, but her closest point was 75 cm. Both have glasses that correct their vision to the point of near-normal eyes (25 cm). One time, because they were not careful their glasses were exchanged and they had different visions than usual. What is the closest distance they can clearly see when wearing glasses that are swapped?

FIGURE 4. An Item about Problem-Solving Ability in Eyes and Glasses

The following is an example of the answer from the *expert* dan *novice* students in solving problems in the item above can be seen in TABLE 3.

TABLE 3. An Example of An Answer from Expert and Novice Student Category

No	Indicator	Categories of Physics Problem Solving Ability: *Expert*	Categories of Physics Problem Solving Ability: *Novice*
1.	***Useful Description*** *N* = 46,2% *E* = 53,8%	Known: $s'_{rendi} = 125$ cm; $s'_{tiara} = 75$ cm ;$s_n = 25$ cm Rendi wears Tiara glasses, and vice versa. Asked: s_{rendi} and s_{tiara} who have a different lens focus than before?	Known : $s'_1 = 125$ cm; $s'_2 = 75$ cm Asked : s_1 and s_2 ?
2.	***Physics Approach*** *N* = 20% *E* = 80%	Both sufferers experience nearsightedness (hypermetropy) because the sufferers' near point to see is greater than 25 cm (normal eye distance). If hypermetropy sufferers have a certain near point using the lens focus (*f*) that is not right, then the viewing distance is still not normal.	Both sufferers experience eye disorders.
3.	***Specific Application of Physics*** *N* = 40% *E* = 60%	Sufferers are helped with a convex lens (positive) to see normal (25 cm). The visible shadow is virtual so s' = - the point near the sufferer. The sufferer uses a convex lens so that it applies: $\frac{1}{f} = \frac{1}{s} + \frac{1}{s'}$ $\frac{1}{f} = \frac{1}{s} + \frac{1}{s'}$ become $\frac{1}{f} = \frac{1}{s_n} + \left(-\frac{1}{s'}\right)$	On the lens applies the equation: $\frac{1}{f} = \frac{1}{s} + \frac{1}{s'}$
4.	***Math Procedures*** *N* = 30,8% *E* = 69,2%	$\frac{1}{f_{Rendi}} = \frac{1}{s} + \left(-\frac{1}{s'_{Rendi}}\right)$; $\frac{1}{f_{Rendi}} = \frac{1}{25} - \frac{1}{125}$; $\frac{1}{f_{Rendi}} = \frac{5-1}{125} = \frac{4}{125}$ $\frac{1}{f_{Rendi}} = \frac{5-1}{125} = \frac{4}{125}$; $f_{Rendi} = 31,25$ cm $f_{Rendi} = 31{,}25$ cm The focus of Rendi's lens for normal viewing is 31,25 cm.	$\frac{1}{f_1} = \frac{1}{s} + \left(-\frac{1}{s'_1}\right)$ $\frac{1}{f_1} = \frac{1}{s} + \left(-\frac{1}{s'_1}\right)$; $\frac{1}{f_1} = \frac{1}{25} - \frac{1}{125}$ $\frac{1}{f_1} = \frac{1}{25} - \frac{1}{125}$

		$\frac{1}{f_{\text{Tiara}}}=\frac{1}{s}+\left(-\frac{1}{s'_{\text{Tiara}}}\right)$ $\frac{1}{f_{\text{Tiara}}}=\frac{1}{s}+\left(-\frac{1}{s'_{\text{Tiara}}}\right)$; $\frac{1}{f_{\text{Tiara}}}=\frac{1}{25}-\frac{1}{75}$ $\frac{1}{f_{\text{Tiara}}}=\frac{1}{25}-\frac{1}{75}$; $\frac{1}{f_{\text{Tiara}}}=\frac{3-1}{75}=\frac{2}{75}$; $\mathbf{f_{Tiara}=37,5\ cm}$ $f_{\text{Tiara}}=37{,}5$ cm The focus of Tiara's lens for normal viewing is 37,5 cm. $\frac{1}{s_{\text{Rendi}}}=\frac{2}{75}+\frac{1}{125}$ $\frac{1}{s_{\text{Rendi}}}=\frac{2}{75}+\frac{1}{125}$; $\frac{1}{s_{\text{Rendi}}}=\frac{10+3}{375}=\frac{13}{375}$ $\frac{1}{s_{\text{Rendi}}}=\frac{10+3}{375}=\frac{13}{375}$; $s_{\text{Rendi}}=28{,}84$ cm $\frac{1}{s_{\text{Tiara}}}=\frac{1}{f_{\text{Rendi}}}+\frac{1}{s'_{\text{Tiara}}}$ $\frac{1}{s_{\text{Tiara}}}=\frac{1}{f_{\text{Rendi}}}+\frac{1}{s'_{\text{Tiara}}}$; $\frac{1}{s_{\text{Tiara}}}=\frac{4}{125}+\frac{1}{75}$ $\frac{1}{s_{\text{Tiara}}}=\frac{4}{125}+\frac{1}{75}$; $\frac{1}{s_{\text{Tiara}}}=\frac{12+5}{375}=\frac{17}{375}$; $s_{\text{Tiara}}=22{,}06$ cm $s_{\text{Tiara}}=22{,}06$ cm	; $\frac{1}{f_1}=\frac{5-1}{125}=\frac{4}{125}$ $\frac{1}{f_1}=\frac{5-1}{125}=\frac{4}{125}$; $f_1=31{,}25$ cm $f_1=31{,}25$ cm $\frac{1}{f_2}=\frac{1}{s}+\left(-\frac{1}{s'_2}\right)$ $\frac{1}{f_2}=\frac{1}{s}+\left(-\frac{1}{s'_2}\right)$; $\frac{1}{f_2}=\frac{1}{25}-\frac{1}{75}$ $\frac{1}{f_2}=\frac{1}{25}-\frac{1}{75}$; $\frac{1}{f_2}=\frac{3-1}{75}=\frac{2}{75}$; $f_2=37{,}5$ cm
5.	***Logical Progression***	Conclusion on the above cases obtained a point near Rendi saw using Tiara's glasses as far as 28,84 cm and Tiara when using Rendi's glasses as far as 22,06	Conclusion on the above cases obtained the distance Rendi saw using Tiara's as far as

N = 15,4% E = 84,6%	cm. This proves that both sufferers still see it unclearly because it is not right with the normal eye distance.	31,25 cm and Tiara when using Rendi's glasses as far as 37,5 cm.

The *useful description* indicator shows that the *expert* students category can describe completely and precisely on each known variable, while the *novice* students category is still having trouble understandings the problem in the item and only writing a few variables without the proper information. The *physics approach* indicator shows that the category of *expert* students understands the concept of glasses as a tool for eye disorders sufferers, while the *novice* students category only write information on the two main characters experiencing eye disorders without explaining qualitatively and detailed. The *specific application of physics* indicator shows that *expert* students can understand the concept of lens focus distance quantitatively by writing the equation and applying it according to the problem, while the *novice* students category only writes the commonly used equations, without relating them to the problem. Students who have extensive knowledge and concepts will be beneficial in determining the solutions that will be used to solve the problem (Docktor & Mestre 2014; Lin & Singh 2015; Kuczmann 2017).

The *mathematical procedure* indicator shows that the *expert* students category can perform mathematical calculations correctly following the procedure to find the right answer, while the *novice* students category performs the calculation but has not yet reached the stage of obtaining completion results because there are still variables that have not been applied. Another difficulty faced by *novice* students is that it correlates between variables correctly to be used at the completion stage, such as the visibility of patients with eye disorders when using an inappropriate lens focus. The *logical progression* indicator shows that the *expert* students category can solve physics problems completely and prove the correctness of the theory in determining the visibility of patients with eye disorders using a particular focus lens (*f*). The *novice* students category made a mistake in solving problems, such as distinguishing the lens' focal point with the point near the eye, so that the conclusions given were not following the problems in the item. This difficulty is also found in previous research, where students did not understand the concepts behind mathematical equations and had difficulty in determining the magnification of shadows on the magnifying glass (Suniati, Sadia & Suhandana 2013; Rokhmah, Sunarno & Masykuri 2017). The other difficulties of students are to provide a scientific explanation of lens function and the formation of shadows on the lens and difficult to distinguish between convex and concave lenses as a viewing aid (Tural 2015).

In addition to students' difficulties in solving problems based on a physics approach, there are still some students who often ignore unit writing and are even mistaken in determining units for certain types of quantities. It will have an impact on the comparison of the measurement results of a certain amount. Some students who have not connected the results obtained with the physics approach so that the students' abilities only get results without interpreting them. It is also found in the students' answers to the three problem-solving questions given (Ding *et al.* 2011; Docktor *et al.* 2015).

The use of learning models should be chosen appropriately, to change the attitude of the students, including students' views on physics affect how they evaluate their learning, so they can think scientifically and can guide students to be more independent, creative and innovative in solving a problem (Hamdani *et al.* 2017; Rerung, Sinon & Widyaningsih, 2017). The popular learning model used in problem-solving is Problem Based Learning (PBL) especially optical instruments in developing students' high order thinking skills at the level of analyzing, evaluating and creating (Nurhayati *et al.* 2017). The use of PBL with media aids and specific strategies will be more effective in improving problem-solving skills than just using PBL (Dwi, Arif & Sentot 2013; Wasiso & Hartono 2013; Hariyanto 2015). Constructing test instruments and designing collaboration skills rubrics related to problem-solving aspects will much support students' ability in identifying problems and evaluating problems scientifically (Sutiadi *et al.* 2016; Hermawan, Siahaan, Suhendi, Kaniawati, Samsudin, Setyadin & Hidayat 2017). Another application to foster student problem-solving competencies is the project-based inquiry approach and problem-based experimental activities so that student has the opportunity to explore training aspects of students' scientific reasoning (Juliyanto *et al.* 2017; Nugraha *et al.* 2017; Sadiqin, Santoso & Sholahuddin 2017).

Some of these recommendations are suggested by the researcher in helping students develop their knowledge to overcome and reduce difficulties in solving problems and improve students' physics problem-solving abilities (Docktor & Mestre 2014; Adams & Wieman 2015).

CONCLUSIONS

Based on data analysis and discussion shows that the students' physics problem-solving abilities of MAN 3 Yogyakarta are still low even though they have taken optical geometry lessons, especially optical instruments. It is evidenced by the achievement of the average overall score of problem-solving and also shown from the percentage of students in the *novice* category higher than students in the *expert* category. *Expert* students solve the problems of optical instruments based on approaches, concepts, principles, and laws that are appropriate, and determine the application of physics correctly as a solution. *Novice* students solve the problem of optical instruments only limited to entering known values into the equation without interpreting them, so the solution given is not appropriate.

The results of this research provide an overview of teachers, educators, and researchers about the condition of problem-solving abilities and the difficulties that students still experience in optical instruments. Therefore, further research is needed to design learning that can train students to improve their ability to solve problems. Besides, educators are expected to understand how students' difficulties are so they can correct and improve physics learning in teaching optical instruments and other physics cases.

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