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Improving Learners' Metacognitive Skills with Self-Regulated Learning based Problem-Solving

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Self-Regulated Learning (SRL) is important to solve learning problems. This research aimed to determine the effect of the problem-solving based Self-Regulated Learning (SRL) strategy on simple harmonic motion material toward the metacognitive abilities of student's senior high school. This research applied a quasi-experimental method with a pre-test and post-test control group design. This research was conducted at Senior high school (SMAN 5 Yogyakarta) with student (n=216). This research used a quasi-experimental method with pre-test-post-test control group design. Sampling was carried out by purposive sampling technique. The instrument used was a test in the form of an essay question sheet and a non-test in the form of a self-regulation journal and student observation sheets. Based on the results of the research, the results of the post-test data hypothesis test for the experimental class and the control class obtained that the calculated Z value was greater than the Z table value (-3.677>-1.96) and the significance value (2-tailed) was 0.001 or less than 0.05. Therefore, the problem-solving based Self-Regulated Learning strategy affected the metacognitive ability of students. Metacognition ability was known on each self-regulation indicator as evidenced by the description of students' answers. It could be found from the N-gain average score, 0.5904, categorized as "moderate". The learners' metacognitive skills were found on each indicator of self-regulation, proven with the descriptions of learners' answers. This learning strategy could be applied as a solution to reflect the learning and learners' cognitive activities in solving physics problems.

Keywords: cognitive activities, metacognition skill, problem-solving, self-regulated learning, simple harmonic motion

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INTRODUCTION

Learning should train the learners to act autonomously and actively in the learning process. It has the purpose to create student-centered activities so they could be habituated to share their knowledge and communicate their learning difficulties. It does not only transfer the knowledge but instead a conscious effort of learners to learn (Jackson et al., 2019). Once learners are aware to learn, they will be able to create the best plan to achieve the goal. It also develops their metacognition skills. Metacognition is a consciousness about the learning process, plan, strategy selection, learning process monitoring, self-improvement and evaluation, and personal learning method and strategy adjustment (Balashov et al., 2020). The learning process sometimes experiences some misconceptions, especially those received by the learners and shared by the teachers. However, metacognition can monitor the thinking stages of the learners so that they could explain their ways of thinking and thoughts (Medina et al., 2017). The metacognition concept consists of metacognitive knowledge, metacognitive skill, and metacognitive experience (Sengul & Katranci, 2012).

Furthermore, Dori et al. (2018) states that metacognition is the skill to connect the important message and the previous knowledge. According to Hassan and Rahman (2017), metacognition is important to improve the learners' skills because it is correlated to planning, monitoring, and evaluating problem-solving. The metacognition development was important because it was the key to achieve meaningful and durable material understanding achievement (Frazier et al., 2021). Furthermore, Rahmat and Chanunan (2018) found that learners who already had metacognitive skills could manage and control their learning. Every individual could develop the self-control stages in learning (Oriol et al., 2017). Meanwhile, the learning should produce a final value to measure the material understanding skills.

Futhermore, Clarke and Roche (2018) revealed that an individual would think to solve a problem once he was engaged with a mathematic problem. The encouragement to solve problems would trigger ideas to prepare and plan the strategies and to solve the problems. The skill to develop it is called self-regulation. It is an aspect of metacognition knowledge (Seufert, 2018). Meanwhile, the problem-solving is a mental activity or an individual's directed attempt to solve and find a correct solution. According to Fauzi and Sa'diyah (2019), applying metacognition-based learning for a physics lesson would facilitate learners to solve physics questions. Metacognitive regulation refers to mental activity. It regulates the cognitive strategies to solve problems (Vula et al., 2017). When self-regulated learning is applied, learners could improve their skills to keep honest, autonomous, and brave. It also allows learners to experience new things to check their weaknesses and strengths in learning science. Thus, the metacognition skill improvement and learners' learning outcomes could be achieved.

The observed metacognition process involved metacognition skills. They were such as knowledge about metacognition and metacognition regulation with self-regulated learning strategy to solve problems. The problem-solving does not refer to skills to identify the applied principles in solving problems but also skills to apply what is learned (Yuliati et al., 2018). It is from the identification into the new situation with different representations or features. Furthermore, Akben (2020) state that teachers must be aware of appropriate problem-solving approaches based on the learners' needs. The eligible learners to solve problems with a qualitative approach would understand the formulas. On the other hand, learners with an excellent understanding of calculation should be encouraged to understand something orally. The problem-solving process cannot be separated from the problem-solving stages. The adopted problem-solving process was identification, determination, exploration, action, look back and learn from applied problem-solving or IDEAL (Li et al., 2021).

Furthermore, Marshman et al. (2018) found that learners with a low understanding of scientific terms would perform lower in identifying the parameters to calculate and have lower confidence Many learners still had difficulties understanding the concept of simple harmonic motion (Ringo et al., 2020). Therefore, Himawan and Winarti (2018) found that the standard of material mastery depended on problem-solving skills. Based on the observation of physics learning at senior high school (SHS), there had not been any implementation of self-regulated learning as the solution to improve the learners' metacognition skills. The achieved learning outcomes of the learners had not been as expected especially about the material of simple harmonic motion. The learning outcomes achieved by students are not as expected, especially in the material of Simple Harmonic Motion. In the learning process of Simple Harmonic Motion, students have not completed the KKM (Minimum Completeness Criteria) yet. This is because there are many equations and material that must be understood, and students are still unable to interpret the initial steps of completing the practice questions and linking them to the appropriate equations for the problem. Thus, the PM-based SRL strategy is expected to be able to overcome the difficulties of students in learning Simple Harmonic Motion material.

SMAN 5 Yogyakarta is a senior high school in Yogyakarta city. The school was established on September 13, 1949. It has a symbol as a philosophical basis called *Puspanegara* tasked by continuing to work and work selflessly for the sake of the fragrance and glory of the country and nation. Many learners had not accomplished the minimum mastery standards of simple harmonic motion. It was due to many equations and materials to understand while the learners could not define the initial problem-solving stage of the question exercise and connect the appropriate equation for the questions. Therefore, Amin et al. (2020) stated the correlation between metacognitive awareness and problem-solving skills still needs to be proven quantitatively, especially in physics. It means that metacognitive and problem-solving skills should be measured with quantitative assessment during learning physics. Some studies had investigated the learners' metacognitive assessments on physics lessons.

Meanwhile, Wade-Jaimes et al. (2018) presented the activities that combined metacognitive instruments with various models (mental, physics, stimulation, and mathematics) in a physics unit of electricity material at SHS. Gray checked the correlation among the metacognitive-self-regulated skills, the physics-self-efficacy, and critical thinking of ninth graders. The multiple regression analysis results revealed that the metacognitive confidence and physics-self-efficacy of the learners were the significant predictors of their critical thinking skills (Gurcay & Ferah, 2018). It was in line with the observation and interview results that showed learners had difficulties understanding and connect the presented data on the question sheet toward the applied equation to solve the problems.

Problems in learning physics in SMAN 5 are students face difficulty in understanding and connecting the data presented in the question sheet with the equations that will be used to solve the problem, especially in the GHS material. Latipah et al. (2021) stated that students have a weak understanding in scientific terms. They are less skilled in identifying parameters for calculations and lack confidence. Students are also less active in the learning process. This occurs because teachers are still unable to facilitate the learning process and thinking skills in solving students' problems with innovative learning models or strategies. Another problem also occurs in students who are less able to regulate and evaluate themselves for the learning difficulties experienced. Thus, they tend to be ordinary and focus on the most important thing being able to work on questions without understanding the material and questions being discussed. Such student activities will have a negative impact if it is conducted continuously. They will not be accustomed to managing cognitive thinking activities. Hence, they will have difficulty solving problems with different types or variables. In addition, Bogdanović et al. (2017) argued that the correlation between metacognitive awareness and problem-solving skills still needs to be proven quantitatively, especially in physics.

The observation results of the learning activities showed that learners were less active during the learning. They had not been habituated and could not determine what strategies to apply to solve the problems. They tended to wait for the answers and explanations of the teachers. They also could not find the solution first. This situation made the teachers ignorant and did not retry or promote self-evaluation. It showed that the on-going learning activities had not facilitated the thinking skills in solving problems and controlling their cognitive activities. From the explanation, problem-solving-based self-regulated learning should be applied for the material of simple harmonic motion so that it could improve the learners' metacognition and monitor their skills to determine the initial stage to solve problems in a physics lesson. The applied physics learning at Yogyakarta SHS had not facilitated the learners' metacognition. The applied learning strategies had not involved learners to evaluate their learning processes. Therefore, this research aims to find out the influence of problem-solving-based self-regulated learning on simple harmonic motion toward the metacognitive skills and to improve the metacognitive skills with the applied strategy. Thus, by applying self-regulated learning, learners would train their physics-problem-solving skills. The learning strategy could also facilitate the learners' metacognitive development that would have important implications to improve learners' learning outcome processes.

METHOD

General Background

This research applied a quasi-experiment to prove the influence of the promoted treatment at Yogyakarta. This research was conducted from February to March 2020. It was carried out in the even semester of the academic year. The applied research design is a pre-test and post-test control group design. This research design had two groups selected randomly. The research design could be seen in Table 1 below.

Table 1
Research design

Groups	Pre-test	Treatment	Post-test
Experiment	Y_1	O	Y_2
Control	Y_1	O_1	Y_2

Based on Table 1, it is known that Y1 is the initial ability of students before being given treatment which is measured through the pretest. Y2 is the final ability of students after being given treatment which is measured through the posttest. Meanwhile, O is treatment given to students in the experimental group and O1 is treatment given to students in the control group.

Participants

This study was conducted in accordance with the contents of the Declaration of Helsinki on research on subjects that include humans. Participants in have agreed to be involved in this study. Consent from each participant needs to be obtained so that this research does not violate Article 20 of the Declaration of Helsinki which states that this research has the right to obtain participant consent after they have received an explanation (World Medical Association, 2013). The population consisted of all tenth graders with 216 participants of 6 classes of the Science and Mathematics Program. From the population, two classes of science and mathematics programs were selected as the control and experimental groups. The applied sampling was the purposive sampling technique. It was considered the most appropriate because the sample was selected carefully based on the research design. It was done by considering the relative features of the learners as the research objects from the same classes. The classes were grouped randomly and received the same learning strategy.

Instruments and Procedures

Metacognitive skills were measured by the MAI that measures metacognitive awareness. The instrument used included self-regulation indicators that covered 6 aspects, there were (1) learning goal orientation, 2) self-control ability, 3) motivation to solve problems, 4) learning outcomes achieved, 5) action settings in achieving learning goals, 6) comparing self-performance with exemplary standard performance. The rating scale used the MAI instrument assessment scale interval created by Educational Research and Evaluation (PEP). However, it was adjusted by looking at the minimum and maximum scores and the number of classes studied. Score measurement used N-Gain.

The techniques of collecting the data were test and non-test. The applied test techniques consisted of pre-test and post-test with essay question item sheets, package A, and package B. Each package contained five-question items based on the indicators of learners' skill achievements. The question instruments of this research were grouped into some question packages. It was to avoid any burden on the learners while working on all questions and the learners did not do the same questions. It was in line with the subjectivity of the questions to be kept and because each class obtained different questions. Each question package contained of 5 questions dealing with the materials. For example, package A it consisted of 5 questions as shown in Figure 1 below.

Question items package A.

1. Explain the definition of period, frequency, deviation, spring constant and amplitude? And draw the equation in simple harmonic motion.
2. For a particle that has simple harmonic motion, what is the magnitude of the velocity and acceleration at maximum and zero displacement?
3. A particle of mass 0.2 kg is at the end of a spring, thus, it is in simple harmonic motion. The position of the particle as a function of time is given by the equation with an amplitude of 0.25m and an angular velocity of 0.1 rad/s. What is the total energy of the particle?
4. Two identical simple harmonic vibration systems A and B, each of mass m, are attached to a spring with a constant force k. If the amplitude of B is 40 cm and the amplitude of A is 20 cm. What is the value of the ratio of the velocities of the two vibrations when their displacements are equal to 10 cm?
5. We often encounter harmonic motion events in daily life, such as a children's swing. If the rope on the swing can be shortened and lengthened. What is the relation between the length of the string and the period? Give your assumption if a child wants the swing to quickly return to the original spot?

Figure 1
Item test for package a

They were such as learning goal orientation, ability to control self, motivation to solve problems, setting actions in achieving goals, comparing self-performance with exemplary standard performance, and learning outcomes achieved. On the other hand, the non-tests were interview and observation by filling the learners' observation sheets. The interview instrument was in the form of an interview sheet containing a list of questions to find out the problems faced by teachers and students in the physics learning process, then provide solutions. The observation instrument was in the form of an observation sheet to find out the activities of students in participating in physics learning by using problem-solving-based Self-Regulated Learning strategies for the experimental class and Discovery Learning strategies for the control class. The learners also filled the self-regulated journals at the end of each meeting. It was used to obtain the learning process reflection data.

Data Analysis

The problem-solving skills were analysed quantitatively with descriptive statistics. The applied descriptive analyses were the test instruments. The test instruments consisted of the validity test with V-Aiken formula and the prerequisite test (Aiken, 1980). The V-Aiken formula was based on the following equation (1) below.

$$V = \frac{\sum s}{N(c-1)} \tag{1}$$

in which: $s = r - l$, with r is the rates of the validators, l is the rater's rating on the lowest category, c is the highest category, and N is the number of the respondents or raters. If the V-Aiken score were equal to or higher than 0.6 (valid ≥ 0.6), the instrument would be categorized as valid and reliable to use. Then, a reliability test was carried out with Cronbach Alpha formula and Nitko formula to test the difficulty levels.

The second test, the prerequisite test consisted of the normality test of pre-test and post-test scores of both groups' problem-solving skills with the Shapiro Wilk test. Then, the next one was the homogeneity test of pre-test and post-test of both groups with the Levene test. Both tests were assisted with SPSS 16.0. The third test was the hypothesis test of both groups' post-test scores with Mann Whitney formula and assisted by SPSS 16.0. The fourth was analysing the metacognitive data obtained from the research. It consisted of metacognitive skill data, the learners' learning outcomes based on the pre-test and post-test, and the self-regulation journal based on the MAI indicators (Metacognitive Awareness Inventory) shared to the learners during the applied strategy.

FINDINGS

The Prerequisite Test Analysis

The prerequisite test analysis consisted of normality and homogeneity tests conducted on the pre-test and post-test data assisted with SPSS 16.0. The normality scores of problem-solving skill pre-test and post-test for both groups based on Shapiro Wilk are presented in Tables 2 and 3 below.

Table 2
The normality test results of pre-test scores

Learning Outcomes			
Group	Shapiro-Wilk Test	df	sig.
Experiment	0.890	36	0.002
Control	0.912	36	0.007

Note: df is degrees of freedom and sig is significance

The normality test results of the problem-solving skill pre-test found that the significant scores of the experimental and control groups were 0.002 and 0.007. The scores are lesser than 0.05, meaning that the pre-test scores were not normally distributed. Then, the post-test scores should be tested in terms of their normalities with the Shapiro Wilk test, presented in Table 3 below.

Table 3
The normality test results of post-test scores

Learning Outcomes			
Group	Shapiro-Wilk Test	df	sig.
Experiment	0.793	36	0.000
Control	0.696	36	0.000

Note: df is degrees of freedom and sig. is significance

The normality test results of the problem-solving skill post-test found that the significant scores of the experimental and control groups were 0.000 and 0.000. It meant both scores' significances were not normally distributed because they were lesser than the significant score, 0.05. The pretest-posttest homogeneity scores of both groups were tested with the Levene test, presented in Tables 4 and 5 below.

Table 4
The homogeneity test results of pre-test scores

The Results of Experimental and Control Groups' Pre-test			
The Levene Test	df1	df2	sig.
3.591	1	70	0.062

Note: df1 is number of data groups-1, df2 is number of data-number of data groups, and sig. is significance

The homogeneity tests of both groups' pretests obtained a significant score of 0.062. It meant the score was higher than the based-on mean significant score, 0.05. Thus, the data were homogeneous. Then, the homogeneity test of the posttest is shown in Table 5.

Table 5
The homogeneity test results of post-test scores

The Results of Experimental and Control Groups' Post-test			
The Levene Test	df1	df2	sig.
1.723	1	70	0.194

Note: df1 is number of data groups-1, df2 is number of data-number of data groups, and sig. is significance

The homogeneity tests of both groups' post-test obtained a significant score of 0.194. It meant the score was higher than the based-on mean significant score, 0.05. Thus, the data were homogeneous. The hypothesis test of this research used a non-parametric statistics test, the Mann-Whitney test. The hypothesis test results of the posttest for both groups are presented in Table 6 below.

Table 6
The hypothesis test results of post-test

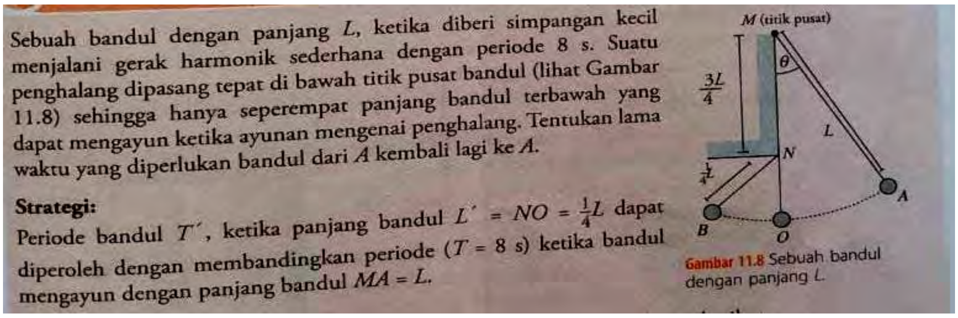
Hypothesis Test	Learning Outcomes
Mann-Whitney Test	333.500
Wilcoxon	999.500
Z	-3.677
Asymp. Sig. (2-tailed)	.001

Note: sig. is significance and Z is Z-count score

The hypothesis test results of both groups' posttests obtained a higher Z-count score than the Z-table score (-3.677 > -1.96) with a sig score of 2-tailed, 0.001, lesser than 0.05. Thus, H_0 was denied, and H_a was accepted. It meant problem-solving skill-based self-regulated learning influenced the metacognitive skills and learning outcomes of the learners.

The Influences of Self-Regulated Learning Strategy toward Metacognitive Skills

The experimental group's learning process was treated with a student worksheet, consisting of 3 to 4 problems to work with the applied problem-solving-based self-regulated learning strategy stages. At the end of each meeting, each learner was given a self-regulation journal as his learning journal to reflect what they had done based on the teacher's direction. The learners filled the self-regulation journal based on the teacher's instructions, about what they had been received during the learning process. Figure 2 shows one of the question items or problems with problem-solving skills and self-regulated learning to do by the learners.



Sebuah bandul dengan panjang L, ketika diberi simpangan kecil menjalani gerak harmonik sederhana dengan periode 8 s. Suatu penghalang dipasang tepat di bawah titik pusat bandul (lihat Gambar 11.8) sehingga hanya seperempat panjang bandul terbawah yang dapat mengayun ketika ayunan mengenai penghalang. Tentukan lama waktu yang diperlukan bandul dari A kembali lagi ke A.

Strategi:
Periode bandul T', ketika panjang bandul $L' = NO = \frac{1}{4}L$ dapat diperoleh dengan membandingkan periode (T = 8 s) ketika bandul mengayun dengan panjang bandul $MA = L$.

Figure 2
The questions worked by the learners

At the first stage, the teacher promoted an apperception for the learners with a discussion material shown in PowerPoint slides and student worksheet. After that, the learners shared various answers with various arguments. From the answers, the teacher found the initial skill of the learners. Then, it was directed to the targeted learning objectives. The learners worked on the student worksheet by writing the problem identifications of the presented problems accurately. The learners wrote the period T, 8 seconds, and the length of the rope l. Then, they could find the frequency f from the given variables with the equation of $f = \frac{1}{T}$. Thus, the obtained frequency was 0.125 Hz.

The second stage required the learners to analyze the presented figures in the questions. They were used to facilitate them working on the questions and to write the length of the required period t to swing from A and return A. The learners wrote $tAA = tAO + tOB + tOB + tOA$ as the initial strategy to determine the following solution. The learners' answers are presented in Figure 3 below.

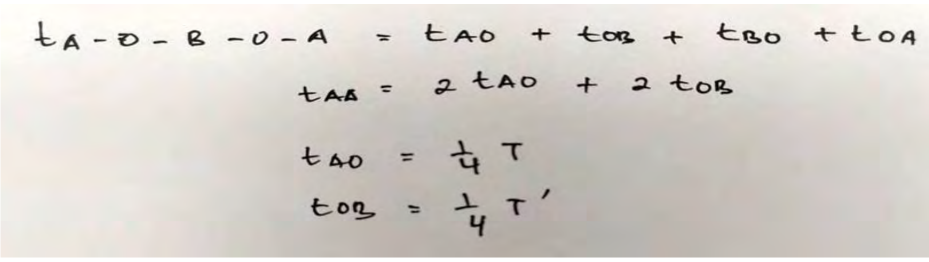


Figure 3
The question solution answers of the learners

The third stage required the learners to operate the planned question solutions as stated in the second stage. Thus, learners could solve the problems systematically and correctly. This stage emphasized inter-peer discussion to develop personal thinking awareness about what strategy should be applied during the situation. The learners wrote the equation of the period. It was $T = 2\pi\sqrt{\frac{l}{g}}$ and operated the equation until they obtained the result, 6 seconds. The learners' answers could be seen in Figure 4 below.

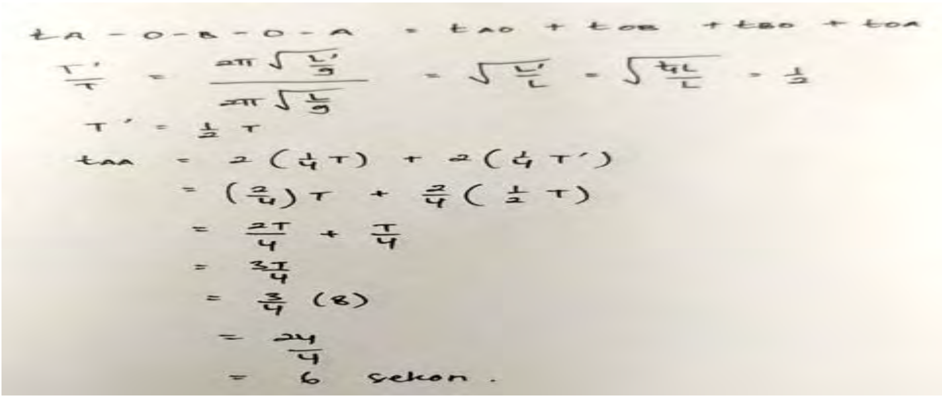


Figure 4
The learners' answers

The fourth stage required the teacher to emphasize the discussed materials about the problems. It was to make the learners understand, remember, and believed in their answers. The learners were directed to evaluate the learning processes during the strategy implementation and determine the problem-solution method. They had to recheck how they operated the equations and processed the data they worked on. The fifth stage required the learners to write the conclusion with the emphasis on the solutions and the answers. Then, they reviewed the solutions by connecting them with the previous materials shared by the teacher.

In the sixth stage, the teacher asked the learners to fill the self-regulated journal. They had to direct the learners to fill the journal so they would write the learning review results honestly. This journal was the medium for the learners to reflect on their learning processes.

The implementation of a problem-solving-based self-regulated learning strategy could improve the self-regulation skills of the learners to support their problem-solving and their metacognitive skills. It was proven with the results of the journal from the experimental group after each ending of the learning. The improvement of the learners' metacognitive skills could be seen from the N-Gain average scores. Here are the N-Gain average score calculations of the learners' learning outcomes, presented in Table 7 below.

Table 7
The n-gain average score descriptions

Group	N	Mean N-Gain	Categories
Experiment	36	0.5904	Moderate
Control	36	0.3065	Moderate

Note: N is number of participants

From the table, the N-gain of the experimental group was higher than the control group. It was 0.5904 higher than 0.3065. Although the N-gain of the experimental group was quantitatively higher it was interpreted to be in the moderate category. It also happened with the control group's N-gain score. Thus, the applied strategy was proven better to improve the metacognition and learning outcomes in terms of learners' problem-solving skills than discovery learning.

Table 8
Test of normality

Gender	Shapiro-Wilk Test		
	Statistic	df	Sig.
Female	0.982	38	0.103
Male	0.891	34	0.247

Note: df is degrees of freedom and sig. is significance

The table shows the analysis of Shapiro Wilk Test. The female learners obtained the score of 0.103 and the value for male student is 0.247. The two results showed higher values than 0.05. It meant the data were normally distributed and could be analysed further with t-test.

Table 9
Different gender and self-regulated learning

SLR Indicators	Female	Male
The orientation of learning objective	3.92	3.21
Self-control skill	3.95	3.54
Self-motivation to solve problems	3.62	3.54
Learning outcome achievement	3.81	3.27
The action regulation	3.93	3.13
Comparison of performance achievement and the standard	3.71	3.02

Table 9 shows from six self-regulated learning indicators, the female learners always obtain higher scores than the men. The first indicator shows the female learners did orientation and wrote the learning objectives. The learners also had differences while organizing their learning. It is in line with the experts' research. They found differences of learners' skills in self-regulated learning and metacognition for both male and female learners (Guo, 2021).

DISCUSSION

Self-regulated learning is strongly correlated to metacognition. Both cannot be separated since they deal with self-awareness, intention, and implementation to act during the learning process (Riley et al., 2021). The student worksheet in the form of problem-solving-based self-regulated learning should be filled by the learners. It made them able to detect the learning process systematically. It could trigger their skills to regulate and support their problem-solving skill to improve their metacognitive skills. The physics learning activities in solving problems in the questions should involve the learners' cognitive and metacognitive activities. It was proven with the results of the journal from the experimental group after each ending of the learning. The results of the self-regulation journals based on the indicators of the first until the last meetings are shown in Figure 4. They show that the applied learning strategy was effective to be a review material of the learning process. Both teachers and learners could review the promoted physics learning process.

Some previous studies had applied self-regulated learning with metacognitive skill indicators. It is in line with Hardy III et al. (2019), that self-regulated learning implementation with metacognitive skills about waste and recycling concept obtained an average score of 83.83. It was categorized excellent and had positive correlation between the variables. It was shown with the determinant coefficient, 58%. The educators and learners could review the promoted physics learning process. Several research also investigated self-regulated learning with the metacognitive skill indicators. After working on some physics problems given by the teacher on the student worksheet with the IDEAL problem-solving stage, it was found that learners could train and find their metacognitive evaluation and regulation.

For example, learners changed their solution and decided to promote problem-solving after applying their metacognitive regulation. On the other hand, when the learners wrote the problem-solving process in a worksheet, they had promoted their cognitive activities. Metacognitive evaluation could be found when the learners filled the journal and assessed their answers after the applied learning process. They did it to assess whether their answers were correct and whether they did it honestly or not for each meeting they experienced. It was in line with Magiera and Zawojewski (2011) that a repeated-rechecking process before assessing what the learners were thinking was the realization of metacognitive evaluation.

The indirect learners' epistemology (mediated by belief and motivation) influenced the exercise strategy, elaboration, organization, critical thinking, and metacognitive-self-regulation for learning physics (Alpaslan et al., 2016). Self-regulated learning was an effective strategy for physics learning. It was since the learners were asked to assess their skills about the concept based on their capabilities (Retnawati et al., 2018). Self-regulated learning is strongly correlated to learners' metacognitions and achievements. Learners could realize their weaknesses. They could manage and select the most appropriate strategies in learning physics. It is in line with studies by Çetin (2017), stated high metacognitive awareness of learners would have higher achievement. The findings found that self-regulated learning and metacognition influenced the learners' achievements.

The application of the problem-solving based SRL strategy used in this GHS material provides stages of independent problem-solving based learning. The teacher presents problem-solving questions to the LKPD (student worksheet) for each lesson and opens a discussion forum for each group. The teacher guides the students by emphasizing the problem-solving process carried out Furthermore, the group representatives presented the results of their discussions. At the end of the lesson the teacher provides a self-regulation journal to find out what is understood and what are the learning difficulties experienced by students. This is conducted to evaluate the learning process for the next meeting.

Problem solving-based SRL strategies were able to have a positive effect on students' metacognitive abilities. With this increase in metacognitive abilities, students also had an increase in their cognitive learning outcomes. This was known from students' answers from self-regulation journals that showed changes in actions from the first meeting to the last meeting during learning. Students knew what was needed while learning and were able to self-evaluate learning difficulties and actions taken after learning. Lack of science learning motivation especially physics on learners became the challenges for learners and teachers. Teachers should select the appropriate strategy with the physics material characteristics. The abstract matter of physics becomes the main matter of the learners to dislike. Thus, learners must struggle to study physics (Olakanmi & Gumbo, 2017). SRL is important in learning physics with abstract matter so learning would be joyful and meaningful. Besides that, SRL also would develop learner' skills to develop cognition, skills, and problem-solving skills (Horowitz et al., 2013). The instructional strategy was applied because it reflected a physics learning that needed conceptual understanding and the mathematics language of the learners. This research is expected to contribute to science-education, metacognition, and self-regulated learning literature.

CONCLUSIONS AND LIMITATIONS

Based on the research objectives, results and discussion, the conclusions of this research are based on the results of the post-test data hypothesis test for the experimental class and the control class, the calculated Z value is greater than the Z table value (-3.677 > -1.96) and a significance value (2-tailed) 0.001 or less than 0.05. It shows that the problem-solving based Self-Regulated Learning strategy influences the metacognitive ability of students. The metacognitive ability of students has increased in each indicator of self-regulation as evidenced by the description of students' answers.

Learning strategies that provide independent problem-solving activities and focus learning on students will encourage students to hone their metacognitive abilities. In which students monitor and correct what they have carried out independently. Furthermore, they communicate what they have understood to someone who is considered an expert such as a subject teacher. This is conducted as an activity to evaluate their abilities. The research that has been conducting by applying the SRL strategy based on problem solving can be used as a strategy. It can make a positive contribution to the metacognitive ability of students. Thus, if students are consciously able to manage their metacognitive activities, they have been able to work on improving their cognitive learning outcomes in studying various materials.

Meanwhile, this research has limitations that can be fixed by further researchers which include the classroom learning activities were carried out in a limited time due to try out for the twelfth graders and the online learning at the end of the meeting. The data collection instruments were only tests (pre-test and post-test), self-regulation journals, and observation sheets. The self-regulation journal was used to facilitate the learning process reflection of the learners. However, it was discussed collectively instead of individually.

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