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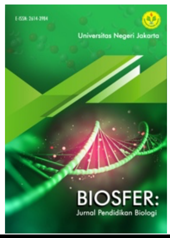

Metacognitive self regulation integrated with science technology society to improving problem solving ability in microbiology courses

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ABSTRACT

The purpose of this study was to improve students' problem-solving ability and metacognitive self-regulation (MSR) by applying science technology society (STS) learning model integrated with metacognitive self-regulation. The participants were 13 students from Department of Biology Education who took microbiology courses. A quasi-experimental method with one-group pre and posttest design was used in this study. Data were collected through pre and posttest with eight open ended questions to measure students' problem-solving ability on four microbiology topics (food, pathogen, waste and water microbiology). These topics were studied sequentially in two months. The instrument used to measure MSR is a questionnaire with open-ended questions. This questionnaire was developed based on three aspects of MSR namely, planning, monitoring and evaluation. MSR questionnaire was administered to students at the end of each topic. The N-gain test was used to analyze the improvement of students' problem-solving ability on each topic. The average score of all aspects in MSR questionnaire was used to explore students' metacognitive self-regulation. The correlation between MSR and problem-solving ability was analyzed using Pearson correlation. The results revealed that the N gain score of problem-solving ability was increased from 0.56 in the first topic to 0.7 in the next three topics. The average of MSR score also increased from 66.15 in the first topic to 87.23 in fourth topic. There was a positive correlation between students' MSR and problem-solving ability. These results indicated that application of Science Technology Society integrated with MSR is an effective strategy in improving students' problem-solving ability and MSR. The implementation of this research is to develop a lecture program as an effort to improve the learning process.

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INTRODUCTION

The activities of Microbes have a wide influence in everyday life. Therefore, people should have microbiological literacy. Introducing microbiology to students is a topic that should be included in curriculum, so it is hoped that in the future it can contribute to the achievement of microbiological literacy in society. The educational curriculum which encourages microbiological literacy should be adjusted to age levels, from pre-school to high school. Contributions from microbiologists or professionals are needed to develop this curriculum (Timmis et al., 2017, 2020) The role of microbes in everyday life can have a positive and negative impact. The example of the negative impact of microbes that is happening at this time is pandemic disease caused by corona virus (COVID 19). Public should know well about this corona virus, how it spread around the world, and what can they do to handle this situation (Amadasun, 2020; Sunil, 2021). Thus, people must understand the basics knowledge of microbes in order to solve the problems. Biology education students are prospective biology teachers who are expected to develop microbiology literacy in community. They took microbiology courses as a part of Biology education curriculum which have goals in applying their knowledge to service the community through projects. For example, students designing lesson plan and its implementation to teach basic information of microbes at elementary school level. They are also expected to act as agents of change who can help solve problems related to microbes. Therefore, microbiology learning should be design to facilitate students' problem-solving ability (Webb, 2016a, 2016b).

Problem solving is a process of finding solution to overcome problems or issues encountered. Problem solving process includes the stages of understanding the problem, devising a plan, carrying out the plan, and looking back (Delvecchio, 2011; Polya, 2004). The Society of microbiologist in American developed a number of programs and educational resources on learning microbiology that encourage the adoption of student-centered learning (Merkel, 2016). One of the student-centered learning models is the problem-based learning model. In microbiology learning, the Case Based Learning (CBL) method is a learning method that trains students to solve problems, improve communication and analysis skills (Date et al., 2016; Sannathimmappa et al., 2019). Other case-based learning models include the Science, Technology, Society (STS) model. is a subject that belongs to the nature of science (NOS) which will have a meaningful learning if it integrates with Science, Technology, Society (STS) in its implementation. The findings from research show that this integration can improve students' understanding of NOS and attitudes towards NOS. In Biology learning, it is suggested to develop and apply the STS strategy (Akcay & Yager, 2010; Bettencourt et al., 2011). The students are expected to understand about science, how to construct their knowledge and how they relate to society by STS models. Students can do science assignments to develop skills which are beneficial to society (Yager, 1992).

In the other hand, the metacognitive approach is known as an effective strategy to develop student' problems solving (Ebomoyi, 2020; Miller & Connolly, 2014). Metacognitive Self-Regulation (MSR) is a self-regulated learning method and self-confidence used by students to change their mental abilities and academic intelligence . Metacognitive strategies can improve social skills and problem-solving abilities significantly (Barber et al., 2011; Eslami Sharbabaki H, 2013; F.Eldhusen, 1995) Metacognitive learning interventions can benefit metacognitive abilities in the long term . Metacognitive Self-Regulation training can improve student performance (Schuster et al., 2020; Spellman et al., 2016) . Metacognitive Self-Regulated is not only related to problem-solving abilities but there is a high-level relationship between Metacognitive Self-regulation and critical thinking skills (Gurcay & Ferah, 2018; Magno, 2010). The other research shows that metacognitive strategy can improve students' learning outcomes on microbiology topics comparing with those who do not use metacognitive strategies (Erlin, 2020; Kristiani et al., 2015). The success of students' learning are influenced by the ability of self-regulation (Sebesta & Speth, 2017; Siegesmund, 2017). Metacognitive training can be used appropriately to develop students' potential in achieving academic achievement (Linden et al., 2021; Saputri & Corebima, 2020).

The results of previous studies examine that the application of case-based learning models through Science Technology Society (STS) and Metacognitive Self-Regulation (MSR) were conducted separately. Downing et al. (2011) stated that students who learned with PBL model had higher metacognitive scores compared to the group of students who used traditional learning methods. Sucilestari & Arizona (2018) revealed that the use of STS integrated inquiry-based science teaching materials is an effective way to increase metacognitive awareness. Metacognitive strategies have a positive impact on problem solving skills which needed to improve academic achievement (Ebomoyi, 2020; Safari & Meskini, 2016). This study is different from previous research in that metacognitive strategies are integrated into the Science Technology Society learning model to improve problem solving abilities and metacognitive abilities.

The purpose of this study was to improve students' problem-solving ability and metacognitive self-regulation (MSR) by applying science technology society (STS) learning model integrated with metacognitive self-regulation. The integration of Metacognitive Self-Regulation in the Science Technology Society will be more effective in achieving learning success, especially in the process of solving problems. The aspects of MSR which including planning, monitoring and evaluating; were integrated at every stage of Science Technology Society learning model. There were three research questions that will be explored in this study:

1. To what extent STS learning model integrated with MSR improved students' problem-solving abilities?
2. To what extent STS learning model integrated with MSR improved students' metacognitive self-regulation?
3. Is there any correlation between students' metacognitive self-regulation and students' problem-solving abilities?

METHODS

Research Design

This study used a quasi-experimental method with a one group pre and posttest design (Creswell, 2014). This method allows research to be carried out on existing groups, thus the experiment can run naturally. Participants were 13 student teachers in 3rd year Biology Education Study Program. This research was conducted on a microbiology course which consists of 4 topics, namely (1) food microbe, (2) pathogenic microbe, (3) waste microbe and (4) water microbe. The research was carried out with these following steps:

1. Designing learning model

STS learning model integrated with MSR consists of four syntaxes, namely invitation, exploration, solution and action plan. This syntax was adapted from the STS feature which refers to NSTA (Yager et al., 2009). Aspects of MSR were integrated in each syntax, which includes planning, monitoring, evaluation (Schraw & Dennison, 1994). Learning activities using this model can be seen in table 1. All learning activities were conducted in two meetings on each microbiology topic. The total time required to complete the courses was 8 weeks. Through this learning model, students are directed to regulate their own learning methods in solving problems discussed on each topic.

Table 1.
Learning activities using model of STS integrated with MSR

No	Syntax of STS	Learning activities (integrated with MSR)	Expected students' MSR
1	Invitation	Teacher prepares students to start learning **(planning)**	Preparing materials for study
		Teacher delivers overview of topic and instructs students to determine goals, strategy, learning resources and time allocation which relevant to the topic **(Planning)**	Determining goals which relevant to the topic Determining strategy to achieve the goals Determining learning resources needed to complete the assignments Setting time allocation
		Teacher asks students to follow the specified instructions **(Planning)**	Following teacher's instruction
		Before starting to study the topic, teacher asks questions to connect students' prior knowledge with topic to be discussed (**Planning)**	Connecting prior knowledge with topic
		Teacher presents daily problems which relevant to the topic, and asks students to formulate questions **(STS)**	Formulating questions to be discussed

No	Syntax of STS	Learning activities (integrated with MSR)	Expected students' MSR
2	Exploration	Students form groups and teacher provides opportunities for students to discuss the questions and exchange experiences /ideas **(STS)** Teacher instructs students to use various leaning resources **(planning)** Teacher asks students to determine important information about the topic **(monitoring)** Students conducting the experiments	Thinking about the strengths and weaknesses in studying the topic Creating concept map or summary about the topic Thinking to obtain information from various resources Obtaining important information to be studied
3	Solution	Students communicate the problem solutions **(STS).** Teacher asks students to: - Assess the accuracy of information **(monitoring)** - Think various ways in solving problems and choose the best solution **(monitoring)** - Determine steps in solving problems **(monitoring)** - Change their strategy when they fail to understand about the topic **(monitoring)**	Assessing the accuracy of information Thinking various ways in solving problems and choosing the best solution Determining steps in solving problems Changing strategy when fail to understand about the topic
4	Action plan	Students asked to create idea about the topic that can be applied to individuals, environment and society **(STS)** Teacher asks questions about: - In what extent students understand the concept - (**evaluating**) - reasons for not understanding the concept and determining strategies to understand the concept (**evaluating**) - benefits of knowledge that has been learned **(evaluate)** Techer assigns students to design the application of products or strategies that will be conveyed to the community (**planning**) Students present their designs	Be aware of concepts that have been and have not been understood Determining strategy to understand the concept Thinking about the benefits of knowledge for they self and society Designing the application of products or strategies for community

Instrument

There were two instruments used in this research. First, the problem-solving ability instrument consists of eight essay questions covering four microbiological topics. Problem solving indicators include: understanding the problem, understanding the causes, determining solutions (G.Polya, 2004; Marzano, Robert J; Kendall, 2007). These questions were given at the beginning and the end of microbiology lesson to measure the effectiveness of learning model in improving students' problem-solving skills. Second, the MSR questionnaire which developed based on three aspects of MSR, namely planning, monitoring and evaluation. The MSR questionnaire referring to Schraw & Dennison (1994). Planning aspects include determining goals and strategies, learning resources, and managing time for assignments completion. Monitoring aspects include monitoring the accuracy of strategies, learning resources, learning styles, and benefits of topic learned. Evaluation aspects include assessing the suitability of goals and conclusions, assessing in what extent students understand the topic, assessing strengths and weaknesses in the learning process. The MSR questionnaire was develop into 20 statements. Students will choose with 'yes' or 'no 'response on each statement. Every 'yes' responses, they must complete it with supporting evidence. Students' responses will be assessed using a rubric on a scale of 1-5. The indicators include planning,monitoring ,evaluating.

Research implementation

At the beginning of the courses, students were given a pretest to measure their initial problem-solving ability. The courses start on topic 1 (food microbes) by carrying out activities using the learning stages in Table 1. At the first meeting, teacher applied invitation and exploration syntax. Solution and action plan syntax were implemented at the next meeting. At the end of topic 1, each student completes MSR questionnaire. They were given time to fill out this questionnaire before the next meeting. Topics 2, 3 and 4 are carried out using the same stages as in Topic 1. At the end of the courses, participants were given a posttest to measure problem solving skills after attending the courses.

Data analysis

The average score of pre and posttest were analyzed using T test. Analysis continued with the calculation of N gain score to determine the effectiveness learning model on students' problem-solving abilities. MSR data were analyzed descriptively by calculating the average MSR score for each topic. This analysis was conducted to explore the implementation of MSR at each meeting. Furthermore, Pearson Correlation was conducted to determine the correlation between students' MSR and problem-solving abilities.

RESULTS AND DISCUSSION

1. To what extent STS learning model integrated with MSR improved students' problem solving abilities?

A study on the application of Science Technology Society learning model integrated with Metacognitive Self-Regulation (MSR) was conducted to obtain information about the effectiveness of those learning model on students' problem-solving ability in the Microbiology courses. Figure 1 shows that the average score of students' problem solving on the four topics has increased at the end of the courses.

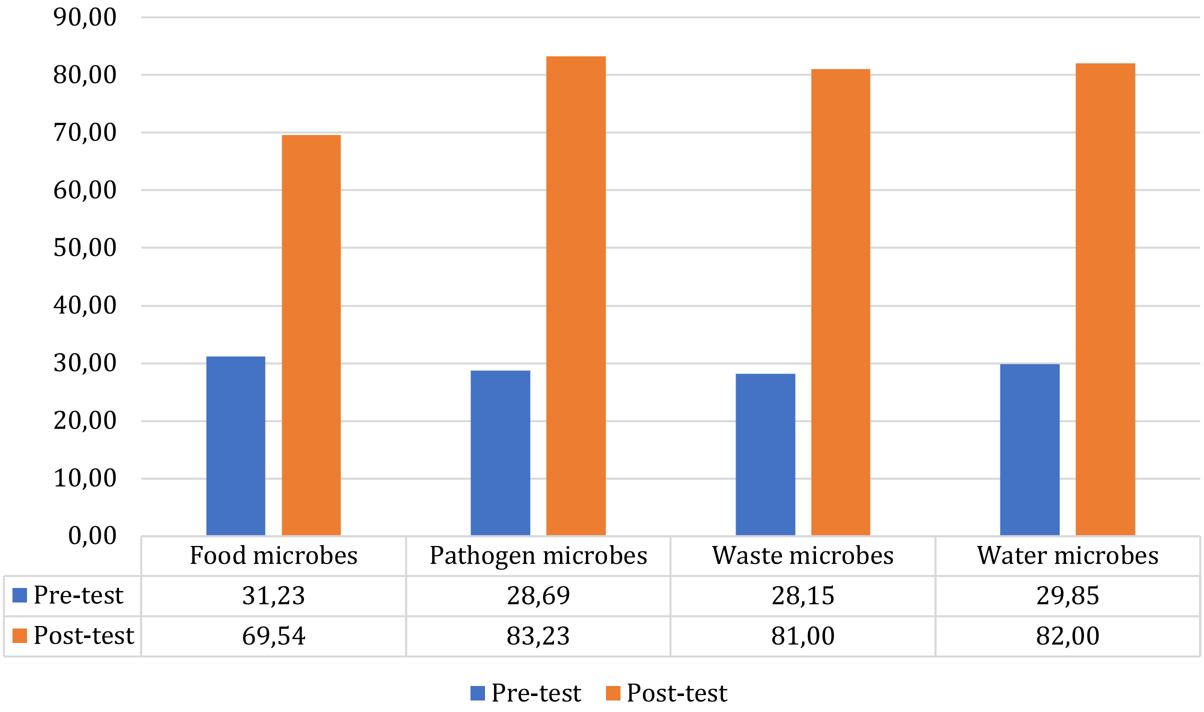

Figure 1. Average Pre-test and Post-test scores

Statistical results using paired sample t-test indicated that there was a significant difference in the average score between pretest and posttest on the four topics (p=0.00). Therefore, the analysis can be continued to N-gain score calculation for each topic. The results of the *N-Gain* score are presented in Figure 2.

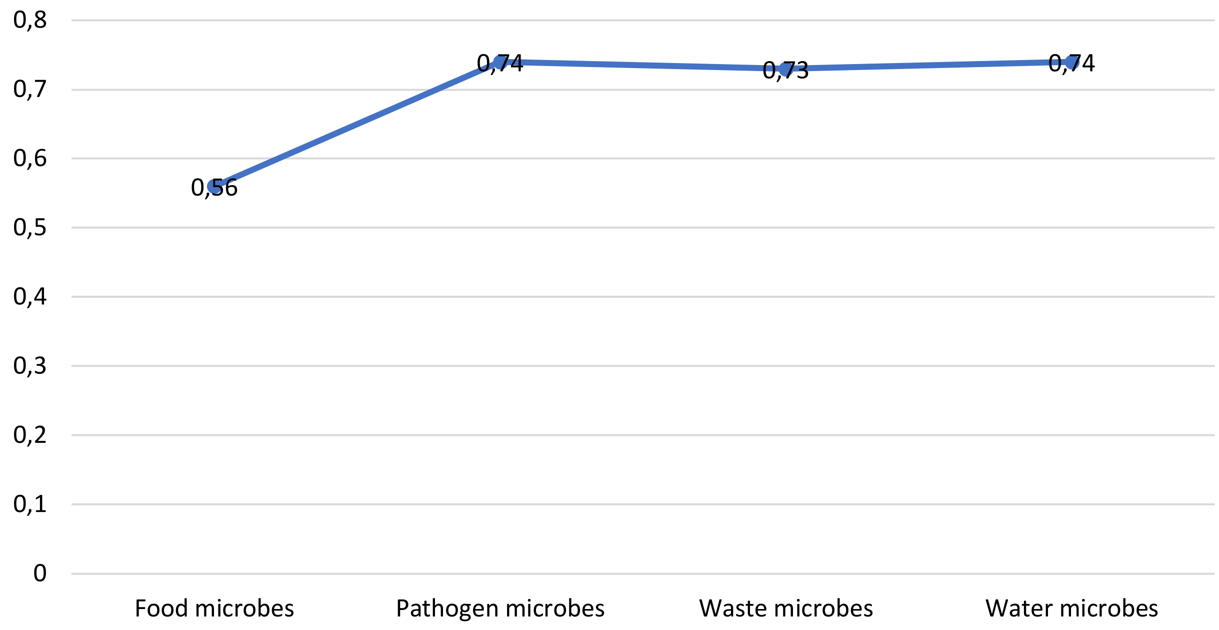

Figure 2. *N-Gain* score on four topics of microbiology courses

Figure 2 shows that the N-Gain score has increased from topic one to the next three topics. Although the N gain score o on the Waste Microbes topic decreased by 0.1 points, the score was still in the high category. At the beginning of the application of the MSR integrated STS learning model in the first topic (food microbe), students' N-gain scores tended to cluster in moderate category (Figure 3). In the second topic (pathogenic microbes), the number of students who got N-gain score in the high category were increased. Likewise, on topics 3 and 4, the N-gain scores of students became clustered in the high category. These results indicate that the MSR integrated STS learning model was effective in improving students' problem-solving abilities.

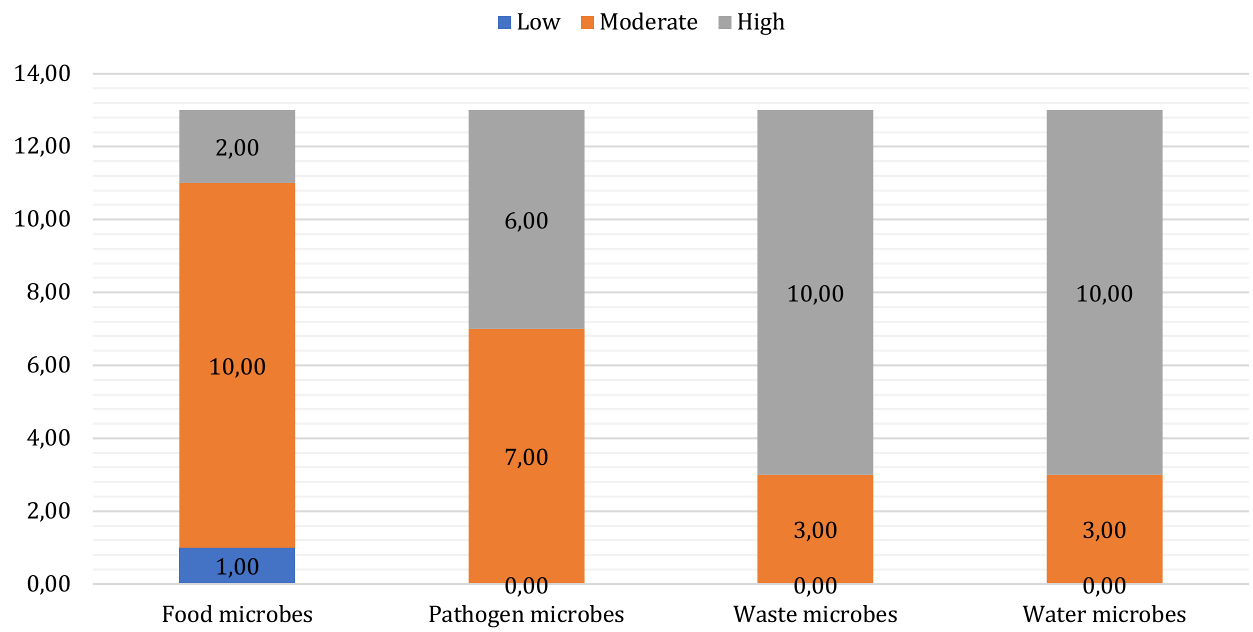

Figure 3. Frequency of N-gain category

The MSR integrated STS learning model provides an opportunity for students to practice implementing MSR strategies which include planning, monitoring and evaluating in each lesson. Through this exercise, students are expected to be accustomed in regulating and controlling their cognitive processes to obtain high learning outcomes, especially in problem-solving process. This result is reinforced by the findings of Freeman et al (Freeman et al., 2017), which states that there is a correlation between metacognitive monitoring and academic achievement. Schneider et al (Schneider et al., 2017) revealed several factors that influence students' achievement, including the stimulation of meaningful learning, social interaction, the application of detailed methods, as well as the following aspects related to the metacognitive process: managing time, designing learning strategies, setting goals and applying feedback.

In addition, the Science Technology Society (STS) model has an effect on students in applying science concepts to new situations in a meaningful way and using their knowledge and skills to solve everyday problems (Kapici et al., 2017). The characteristics of STS according to NSTA standards are identifying problems and utilizing resources to obtain information that can be used to solve problems (NRC, 1996) . STS learning focuses on process skills, emphasizing careers related to science and technology, providing opportunities for students to solve problems and identify ways that science and technology may have impact on the future, through the application of STS, students have a wealth of experience in understanding and investigating the universe. They also can use appropriate scientific processes and principles when making decisions or designing solutions to solve problems by producing useful products with economic value (NRC, 1996; Yager et al., 2009).

2. To what extent STS learning model integrated with MSR improved students' MSR?

The MSR questionnaire analysis revealed that the average score of MSR implementation on four microbiological topics increased (Figure 4). These increasing indicate that the application of the STS integrated MSR learning model can improve the implementation of metacognitive self-regulation. Figure 4 showed that the average score of MSR implementation in the early stage was lower than the implementation to the next three topics. In the early stage, students were still adapting to use MSR strategy in their learning. They have never used this strategy before, so they were not used to organizing themselves to achieve their learning target desired.

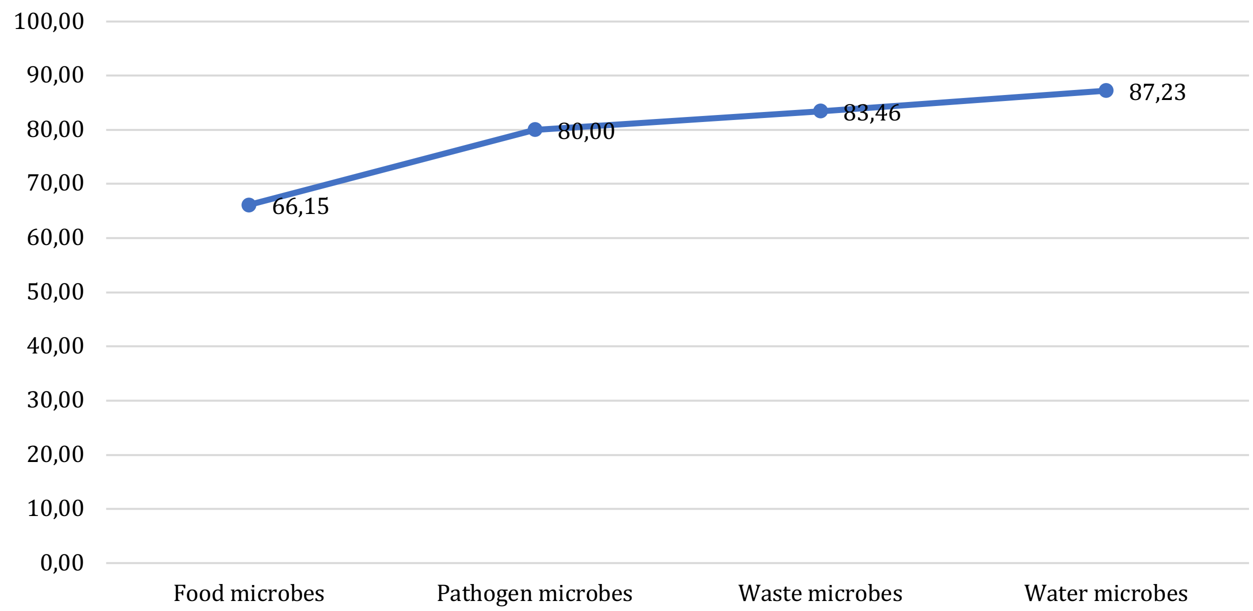

Figure 4. Average score of MSR implementation on four topics

The application of Metacognitive Self-Regulation requires practice and habituation. The results of research on metacognitive learning strategies show that the use of metacognitive learning strategies can increase significantly during one semester in a learning environment with increased opportunities for Self-Regulated learning (Vrieling et al., 2012).Suggested that it is necessary to observe students' changes caused by Metacognitive Self-Regulation in every week (Isaacson & Fujita, 2006). These shows that the habituation of Metacognitive Self-Regulation takes a relatively long time. Students' competence in self-regulation can be increased through systematic interventions designed to improve students' skills and self-efficacy (Schunk Dale H & & Ertmer, 2000). Schunk concluded that students' self-regulation is determined by how often and how well they use it.

Metacognitive strategy is one way to develop student self-regulation. Metacognitive strategies consist of knowledge about cognition and cognitive regulation which includes planning, monitoring, evaluation or regulation (Mytkowicz & Steinberg, 2009; Pintrich et al., 1993; Schneider et al., 2017; Schraw & Dennison, 1994). Efforts to increase metacognitive awareness can be done by suggesting students to ask themselves about planning, monitoring and evaluation that will be applied in their learning. Some questions about planning include: what is the purpose of doing this task? What things do I need to do to successfully complete this task? How long will it take to complete this task? What strategies can be used? What resources can be used? An example of a monitoring question include: can I do this job well? What do I not understand? Furthermore, questions that can be asked for evaluation include: Have I achieved the objectives of this assignment? What are my strengths and weaknesses in completing this task? ((Tanner, 2012) . If these MSR aspects are realized repeatedly, it is hoped that it will have an impact on improving MSR implementation. Therefore, in the next three topics inn figure 4, the score of MSR implementation is increasing. These results indicate that the learning model of STS integrated with MSR can train students to organize themselves to achieve their learning.

3. Is there any correlation between students' metacognitive self-regulation and students' problem-solving abilities?

The results of statistical analysis using Pearson Correlation showed that there was a strong positive relationship (r=0.95) between the mean score of MSR implementation and the average N-gain score of problem-solving ability (Figure 5). This indicates that students who have good Metacognitive Self-Regulation are able to solve problems well.

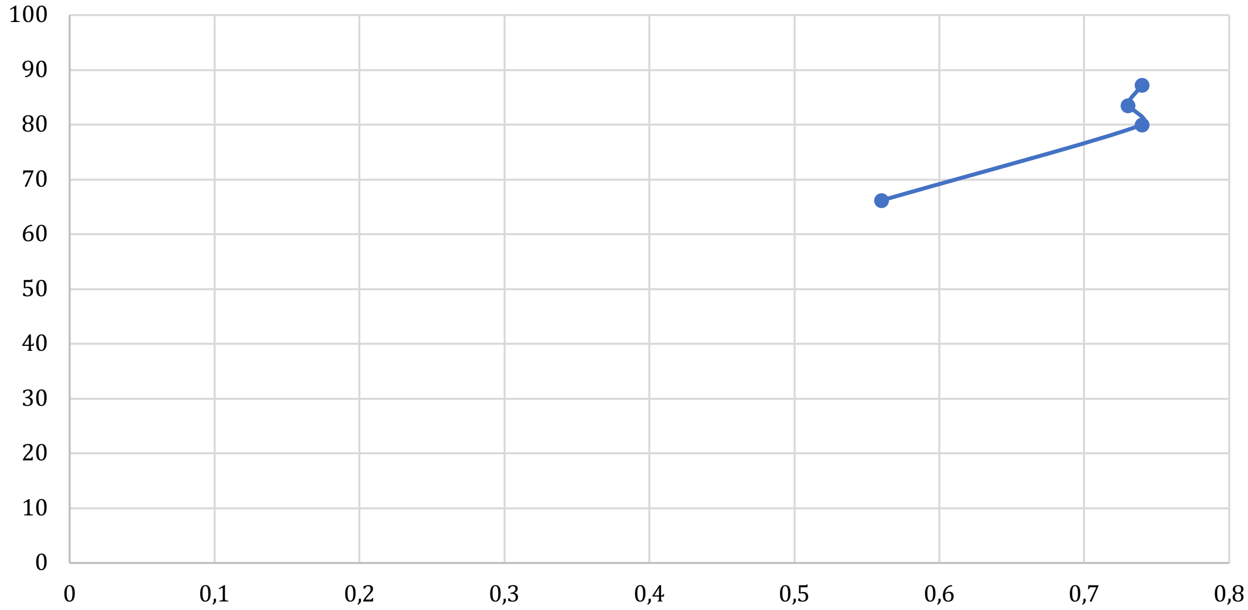

Figure 5. The correlation between MSR and problem-solving ability

The results of this study are supported by the findings of the research which states that high metacognitive abilities can positively affect problem solving performance (Swanson, 1990). Metacognitive strategies are recommended to be taught because these strategies have a positive effect on problem solving and academic achievement (Safari & Meskini, 2016). Self-regulation is a proactive process that students use to acquire academic skills, such as setting goals, selecting and implementing strategies, and monitoring the effectiveness of their own learning (Zimmerman, 2008) . The level of student learning independence is determined by their independence in determining goals and strategies to achieve goals, self-monitoring, time management, learning environment management, regulatory efforts and self-evaluation (Pintrich et al., 1993). In implementing the metacognitive self-regulation strategy, students not only carry out cognitive activities in the problem-solving process, but also need effective instructions for independent learning, including setting certain goals, planning activities, monitoring their performance and evaluating the efficiency of their actions during the problem-solving process. These general instructions help to develop cognitive structures when solving problems (Ifenthaler, 2012) . The application of metacognitive strategies in this study was carried out by peer learning, where this application is supported by research which states that metacognition and peer learning have a positive effect on problem solving and have potential to improve microbiology learning outcomes (Ebomoyi, 2020). The results of this study are supported by the opinion which states that self-monitoring on metacognitive is very important in the problem-solving process, because in this process students must be able to control their thoughts or be aware of the goals and strategies that will be used to achieve goals and predict the effects of using these strategies (Martinez, 2015).

CONCLUSION

This study shows that STS integrated with MSR learning model was effective in improving students' ability to solve problems in microbiology courses. In addition, the application of this learning model can encourage the implementation of Metacognitive Self-Regulation, where students are directed to plan, monitor and evaluate their way to learn. This study also states that there was a strong positive correlation between MSR score and N-gain score of problem solving. This indicates that students who have a good MSR will have good problem-solving skills as well. In the next stage, these results can be implemented to develop a course program as an effort to improve the learning process, both in microbiology courses or other biology courses.

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