Jurnal Inovasi Teknologi Pembelajaran
Vol 10, No 1, (2023), page 71-82
https://doi.org/10.17977/um031v10i12023p071
P-ISSN: 2406-8780 E-ISSN: 2654-7953
Open access: http://journal2.um.ac.id/index.php/jinotep/index

Innovation for measuring students' metacognitive abilities through project-based learning

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ARTICLE INFO

Article history:
Received: 13-01-2023
Revised: 02-03-2023
Accepted: 12-03-2023

Kata kunci:
Metakognitif;
Proyek Biologi;
Pembelajaran berbasis proyek.

Keywords:
Metacognitive;
Biology projects;
Project-based Learning

ABSTRACT

Kemampuan metakognitif dinilai berpengaruh terhadap bagaimana peserta didik dapat belajar secara mandiri untuk memperoleh prestasi akademik. Untuk itu, penelitian ini bertujuan untuk mengukur bagaimana pembelajaran berbasis proyek dapat meningkatkan kemampuan metakognitif peserta didik dan mengidentifikasi kesadaran metakognitif peserta didik dalam pembelajaran. Data dalam penelitian ini dikumpulkan melalui pretest, posttest, observasi, dan angket kesadaran metakognitif. Data-data tersebut dianalisis secara kuantitatif dan kualitatif untuk menghasilkan pemahaman yang lebih baik tentang masalah dan hasil penelitian. Hasilnya, kemampuan peserta didik dalam memecahkan masalah metakognitif mengalami peningkatan. Indeks Gain yang diperoleh dari rata-rata hasil belajar peserta didik adalah 0.7, yang berarti memiliki signifikansi peningkatan yang tinggi. Dijelaskan pula bahwa kemampuan metakognitif mereka berkembang dilihat dari perubahan kategori kemampuan mereka yang diobservasi selama pelaksanaan proyek. Kesadaran metakognitif peserta didik setelah pembelajaran berbasis proyek mulai tampak pada beberapa aspek, di antaranya strategi pencarian dan perencanaan.

ABSTRACT

Metacognitive abilities can influence how students learn independently to achieve academic success. For this reason, the study aimed to examine how project-based learning can enhance students' metacognitive abilities and identify students' metacognitive awareness. To understand those goals, three steps of data collection were done, including pre-test, post-test, observation, and questionnaires. Both quantitative and qualitative approaches were conducted to better understand the problem and the results. As a result, the ability of students to solve metacognitive problems has improved. The Gain index from the student learning process is 0.7, means it has a significant increase. It was also explained that their metacognitive abilities had developed judging by the changes in their ability categories that were observed during project implementation. Several aspects, including search strategy and planning, were evident in students' metacognitive awareness after project-based learning.

INTRODUCTION

Facing the demands of the 21st Century, students need to be directed to develop skills that are useful for their lives after school. The skills needed to face global competition in the 21st century that entail mastery of knowledge in a scientific discipline and affective experiences or soft skills such as good work attitude, self-confidence, responsibility, social and communication skills, self-motivation, flexibility, and self-management (Lai & Viering, 2012; Musa et al., 2012). At least there are several main skills in 21st century skills, namely life and career skills, skills in learning, thinking, and skills in the use and utilization of information and communication technology (Musa et al., 2012; Wan Husin et al., 2016). These skills are expected to enable students to carry out their roles effectively both when they are in the school environment and the after-school environment.

One of the 21st-century skill frameworks is the framework prepared by the 21st Century skills assessment and learning organization namely assessment and teaching of 21st century skills organization (ATC 21). Within this framework are four groups of skills consisting of ways of thinking, ways of working, tools for working, and living in the world (Lai & Viering, 2012) . One of the skills included in the ways of thinking framework compiled by ATC 21 is metacognitive ability in learning.

Metacognitive abilities are abilities that have been widely studied in recent years. Those are essential to measure because they are considered influential in the development of students' cognition. For this reason, metacognitive abilities are a research focus that is being developed in addition to research on other students' abilities. Research on metacognitive abilities is carried out to be able to identify and develop metacognitive ways of thinking in students. In these studies, it is stated that metacognitive training can help students get used to using their knowledge (McCabe, 2011; Sonowal & Kalita, 2017). In addition, the development of metacognitive ways of thinking can influence student learning outcomes (Iskandar, 2014). According to him, activities that can familiarize the use of metacognitive abilities can positively influence the learning process, even if they are only involved for a short period.

Metacognitive is correlated to knowledge about cognition: knowledge about thought processes that occur within a person. Metacognitive helps a person be aware of and responsible for their thoughts and knowledge (Sonowal & Kalita, 2017). Metacognitive abilities are abilities that provide opportunities for students to be able to determine better strategies in using the knowledge they have. In addition, metacognitive abilities are considered a particular ability structure that can enable students to determine more efficient ways of learning (Lai & Viering, 2012; Sart, 2014). Metacognitive abilities are assessed as abilities that describe independence in thinking, learning, and evaluating the processes one is living. Therefore, students can develop the knowledge they have for their own needs in learning (Sart, 2014).

The explanation above illustrates that metacognitive ability is a crucial ability to be possessed by someone, especially students. Learners need metacognitive abilities while they are learning. However, it turns out that some of the students at school do not recognize that they have abilities to develop to help them use good strategies in learning (McCabe, 2011). Furthermore, the abilities of introduction, inculcation, and measurement have not be a focus in learning process in schools. Students' learning process, including how they obtain information and use it, is frequently neglected by teachers. Learning in schools is often focused on the content of the material (Djudin, 2017). In fact, the metacognitive abilities of most students, especially high school students, have started to develop (Sholihah et al., 2015). This ability still needs to be improved by providing learning that can stimulate the metacognitive abilities development in students so that in the end, students do not only have metacognitive abilities, but are also skilled at using them.

Based on the characteristics described above, metacognitive abilities need to be developed in every learning process, including in the implementation of Biology learning. When students study Biology, they are not only encouraged to study knowledge about living things and their environment but also cultivate attitudes, responsibilities, and thinking skills in carrying out investigations related to the nature around them. In learning biology, metacognitive abilities will also assist students in planning to investigate Biological objects, familiarize themselves with learning independence, and help students find, select, and define relevant Biological concepts and principles to solve life-related problems (Purwanto et al., 2018).

Project-based learning is one of the approach that can be conducted in class to develop metacognitive abilities (Sart, 2014; Wan Husin et al., 2016). Project-based learning supports students in planning, implementing, evaluating, and solving problems (Sart, 2014; Wan Husin et al., 2016). According to Sart (2014), the results of his research indicate that project-based learning can support the development of metacognitive ways of thinking that will affect the learning outcomes obtained by students. The Gold Project Based Learning design by Larmer (2019) features at least eight project-based learning designs starting with problem identification, planning, monitoring, and evaluating. Therefore, project-based learning will provide opportunities for students to enhance their metacognitive abilities through project planning, monitoring, and evaluation.

Project-based learning will provide meaningful learning if it presents projects that are close and impact students' lives. One issue that is close and needs to find a solution is environmental issues, such as the issue of waste management to protect the environment. Environmental issues are issues that require more attention, especially by students as the next generation. This is because students as the next generation are the ones who will inherit nature and everything in it. According to Hernandez and colleagues, environmental problems that arise are not just a matter of ecological aspects, but of knowledge and education imparted to generations on earth (Valderrama-Hernández et al., 2017). Adequate education is needed to create active participation and creative efforts from students in solving environmental problems, one of which can be done by applying the project method in learning (Derevenskaia, 2014). Of course, the learning that is presented must bring up new knowledge and/or technology that can provide environmental insight for students. Thus, the learning projects presented can bring students to become human beings who carry out their roles as good members of society. This is appropriate to fulfill the 21st-century skills framework, one of which is how to be a member of society who lives in the world well (*living in the world).* This issue can be raised in schools through Biology project-based learning. As we know, environmental material is one of the materials taught at both middle and high school levels. In senior high schools, environmental material is contained in basic competencies 3.11 and 4.11 which include material on environmental change, environmental damage or pollution, mitigation, and disasters, as well as waste and waste recycling.

The project to be raised in this research is decomposing organic waste using *Hermetia illucens* larvae / *Black Soldier Fly* (BSF) which have been widely studied so far. The research results have greatly influenced the processing of organic waste in several countries (Dortmans et al., 2017). In Indonesia, similar studies have also been carried out. Research on Black Soldier Fly (BSF) that has been carried out includes research on processing organic waste and solid organic waste in urban areas (Monita et al., 2017; Saragi and Bagastyo, 2015). However, in terms of implementation and dissemination of the research results, they are not widely disseminated and utilized in society, especially through education. Derevenskaia (2014) provides the opinion that issues that are close to the community, such as the issue of organic waste management, need to be introduced through project-based learning in schools. According to him, project-based learning like that needs to be done to create critical thinking and creative action from students to solve environmental problems around them, which in this case is the problem of organic waste. On this grounds, this research also seeks to disseminate and implement information on research results, especially in the decomposition of organic waste, so that it will have a broader impact on society. Based on the explanation above, this study uses project-based learning in biology subjects to develop students' metacognitive abilities. Using project-based learning, this study will examine how students perform on metacognitive tests in biology.

METHOD

This research was conducted with the *embedded mix method design*. This method is used to collect, analyze, and integrate quantitative and qualitative data in a single study. This research was conducted by applying project-based learning to 44 high school class X students at a private school in Bandung. Quantitative and qualitative data collection is carried out simultaneously using predetermined instruments. Data collection carried out in this study included quantitative data collection before and after treatment, as well as qualitative data during the treatment in learning.

This learning lasted for three meetings with 15 days of learning and project implementation. The project used as content in this project-based learning is the decomposition of organic waste using *Hermetia illucens larvae.*

Students are given metacognitive ability test questions before and after project-based learning in Biology subjects. The questions used were five descriptive questions consisting of eleven items representing the components of metacognitive ability indicators (Table 1). The indicators of metacognitive abilities compiled in the metacognitive ability test questions, including strategic knowledge, cognitive task knowledge, and self-knowledge. The strategic knowledge component consists of a) determining the objectives of the project being carried out, b) detailing what needs to be prepared/studied, c) determining some alternative solutions about problems, and d) providing relevant arguments in selecting some alternative ways of solving the problem. The components of cognitive task knowledge consist of a) choosing information appropriate to the task being performed, b) determining the steps in managing the time for doing the task, and c) determining the steps in the division of the task to be carried out. The self-knowledge component consists of a) giving an explanation of the efforts that have been made in solving the problem, b) detailing the concepts that have been and have not been understood about the task or project, and c) determining the extent of one's ability to realize the idea or project.

This metacognitive ability test has previously been tested with good results. The analysis results show that the average score obtained at *the pretest* is 8.55, with a standard deviation of 2.16. The X->Y correlation is 0.54, and the reliability or constancy of the question package is 0.70. There is a *posttest* question. The X->Y correlation obtained is 0.60, and the reliability or constancy of the question package is 0.75. Based on the test results, all questions were used in conducting the research because they were appropriate, met the requirements for the distribution of difficulty levels, and had sufficient reliability. Table 1 provides metacognitive questions used in this study.

Table 1. Grid of metacognitive questions

Components and Indicators of Metacognitive Ability	Question Item Number	Cognitive Level			
		C2	C3	C4	C5
Strategic Knowledge					
1. Determine the objectives of the project undertaken	1a			√	
	1b			√	
2. Specify what things need to be prepared / studied	1 c		√		
3. Determine several alternative solutions to the problem	2a			√	
4. Provide relevant arguments in choosing one of several alternative ways to solve the problem	2b				√
Cognitive Task Knowledge					
1. Choose the appropriate information for the task being performed	3a			√	
2. Determine the steps in managing the time to complete the task	3b		√		
3. Determine the steps in the division of tasks to be carried out	3c		√		
Self-Knowledge					
1. Give an explanation of the efforts that have been made in solving the problem	4a				√
2. Detailing concepts that have been and have not been understood about tasks/projects.	4b	√			
3. Determine the extent of one's ability to realize ideas or projects.	5				√

Table 2. Grid metacognitive awareness inventory

Category	Statement Points
Declarative knowledge 1. Factual knowledge needed by the learner before being able to process or use critical thinking related to the topic 2. Knowing about, what, or that 3. Knowledge of one's skills, intellectual resources, and abilities as a learner 4. Students can gain knowledge through presentations, demonstrations, discussions	Statement number: 5; 10; 12; 16; 17; 20; 32; and 46
Procedure knowledge 5. Application of knowledge for the purpose of completing a procedure or process 6. Knowledge of how to apply learning procedures (e.g., strategies) 7. Requires students to know the process and when to apply the process in various situations 8. Students can gain knowledge through discovery, cooperative learning, and problem solving	Statement number: 3; 14; 27; and 33
Conditional knowledge 9. Determination under what circumstances specific processes or skills should be transferred 10. Knowledge of when and why to use learning procedures 11. Application of declarative and procedural knowledge to the specific conditions presented 12. Students can gain knowledge through simulation	Statement number: 15; 18; 26; 29; and 35
Planning 13. Plan, set goals, and allocate resources before learning	Statement number: 4; 6; 8; 22; 23; 42; and 45
Information management strategy 14. Skills and sequences of strategies used to process information more efficiently (e.g., organizing, elaborating, summarizing, selective focus)	Statement number: 9; 13; 30; 31; 37; 39; 41; 43; 47; and 48
Comprehension monitoring 15. Assessment of the use of one's learning or strategy	Statement number: 1; 2; 11; 21; 28; 34; and 49
Tracking strategy 16. Strategies for correcting misconceptions and performance	Statement number: 25; 40; 44; 51; and 52
Evaluation 17. Analysis of the performance and effectiveness of the strategy after the learning episode	Statement number: 7; 19; 24; 36; 38; and 50

During the learning process, students are observed using observation sheets that have been assessed by experts. In the end, a metacognitive awareness assessment is administered to students in Indonesia based on the metacognitive awareness inventory (MAI). This assessment was employed to identify the metacognitive awareness of students, ultimately used to determine their ability categories. Several aspects are in the 52 statements related to MAI as can be seen in Table 2.

Analysis of the research data was conducted based on the results of the values of each instrument used. The success criteria include the N-Gain score and ability category. The Gain Index of the results of this test is calculated to show the significance of the increase in results between before and after the project-based learning implementation. The gain index test in this study was used to qualitatively determine the increase in metacognition abilities possessed by students after learning. The categorization of metacognitive abilities is not based on the acquisition of student scores, but is seen from how students express their ideas. The categorization of metacognitive abilities was done by referring to the categorization compiled by Cambridge Assessment International Education (CAIE) (2017). The categories used are *tacit* (passive), *aware* (tentative), *strategic,* and *reflective*.

RESULTS

The overall data was obtained from 44 students in two classes. They took part in the three meetings of the learning process. The 44 data consisted of *pretest* and posttest, respectively. Metacognitive ability data during project-based learning was taken through metacognitive ability test questions that were carried out prior to and after project-based learning activities. The average *pretest score* of students is 71.7, while the *posttest score* is 91.1. The average increase in students' scores from pretest *to* posttest *was* 19.4 points. After that, its value is calculated to find out the Gain index.

Table 3 shows the calculation of the Gain index from students' pretest and posttest results. The Gain index value obtained is 0.7 (rounded off), which means that the Gain Index calculation shows a high significance increase between the *pretest* and *posttest scores.* The following table shows the students' highest and lowest pre-tests and post-tests scores, as well as gains calculated from the data. Students' metacognitive abilities also can be seen from the students' answers categories. There are four metacognitive categories employed in this study, which are *Tacit, Aware, Strategic,* and *Reflective* (Cambridge Assessment International Education, 2017). Those four classifications are sequential.

Figure 1 depicts the student answers categories during pretest (before the intervention). In the figure, most students populate the *tacit* and *aware categories*. The most number populated by tacit category is item number 5. In this question, students are involved to evaluate their own ability doing a project by explaining the waste decomposition project plan. The strategic category began to appear in small numbers in the pre-learning test, whereas the reflective category did not appear. Achievements prior to the implementation of project-based learning on organic waste decomposition demonstrate students' abilities prior to the development of metacognitive strategies in class instruction.

Table 3. Gain index calculation

Test variables	Pre-test	Post-test
Lowest Value	36,4	45.5
The highest score	90.9	100
Overall Average	71.7	91.1
Gains Index	$<G> = \frac{T2-T1}{S1-T1}$ $<G> = \frac{91.1-71.7}{100-71.7}$ $<G> = \frac{19,4}{28,3}$ <G> = 0.6855 (0.7) (High)	

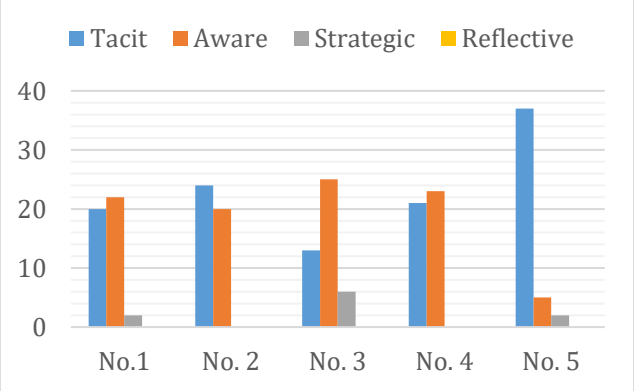

Figure 1. Diagram of students' answers categories on the pre-test

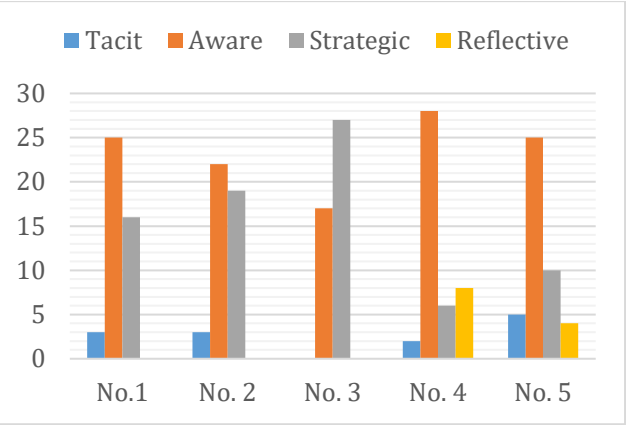

Figure 2. Diagram of the categories of students' answers on the post-test

Figure 2 illustrates the categories of students' response during *posttest.* The figure shows that the categories of answers that dominate the *posttest* are *the aware* and *strategic categories*. *Tacit* categories appear in significantly fewer numbers than *pretest*. Students' answers on *the posttest* began to bring up the *reflective category*. The highest category in this metacognitive ability begins to appear in item number 4 and number 5.

According to the findings of this study, students' metacognitive abilities enhanced generally after being involved in decompose organic waste project-based learning. This increase is indicated by an increase in *posttest scores* for students who participate in the whole lesson. The achievement of good grades was also seen from the shift in the ability categories of students during *the pretest* and *posttest*. The ability category that dominates *the pretest* is the *tacit category,* while the ability category that dominates *the posttest* is *the aware* and *strategic category*.

During project learning, students are observed using observation sheets. This observation sheet contains a series of project stages designed to see students' abilities in planning, designing, criticizing, and revising. There are 8 phases in learning in the project-based learning design that is being carried out. The eight phases are *key knowledge, understanding, and success skills* (the phase of setting learning objectives), *challenging problems or questions* (determining basic problems/questions), *sustained inquiry* (advanced investigations), *authenticity* (determining authentic projects), *student voice and choice* (choose and voice), *reflection*, *critique and revision* (criticism and revision), and *public product*.

The results of observations during learning will be translated in the form of implementation percentage points and descriptions. The results of the assessments carried out in the three meetings obtained an average score of 39.75 out of a maximum score of 43 (Table 4). This value indicates that almost all of the criteria (92.4%) in the observation sheet evaluating the implementation of learning were achieved. In addition, the observer also recorded significant points that could be an additional assessment of improving students' metacognitive abilities. Table 4 shows the results of the assessment using the observation sheet on the implementation of project-based learning conducted in this study. Based on Table 4 regarding the results of observing learning activities, some criteria in the eight phases of project-based learning are not appropriately implemented. These sections include the first and second phases of questioning activities. In addition, when students carry out the *authenticity phase*, where the activity of listening and providing input regarding project plans, participants focus more on their respective projects. Furthermore, in the project implementation process, the activity that faces obstacles is during the larval breeding process. In addition, all project activities carried out can run well.

Table 4. Results of observation of learning activities

Observers	Grade 1 score	Grade 2 score	Mark (average)	Percentage (%)
A	40	40	40	93
B	39	40	39.5	91.8
Average	**39.5**	**40**	**39.75**	**92.4**

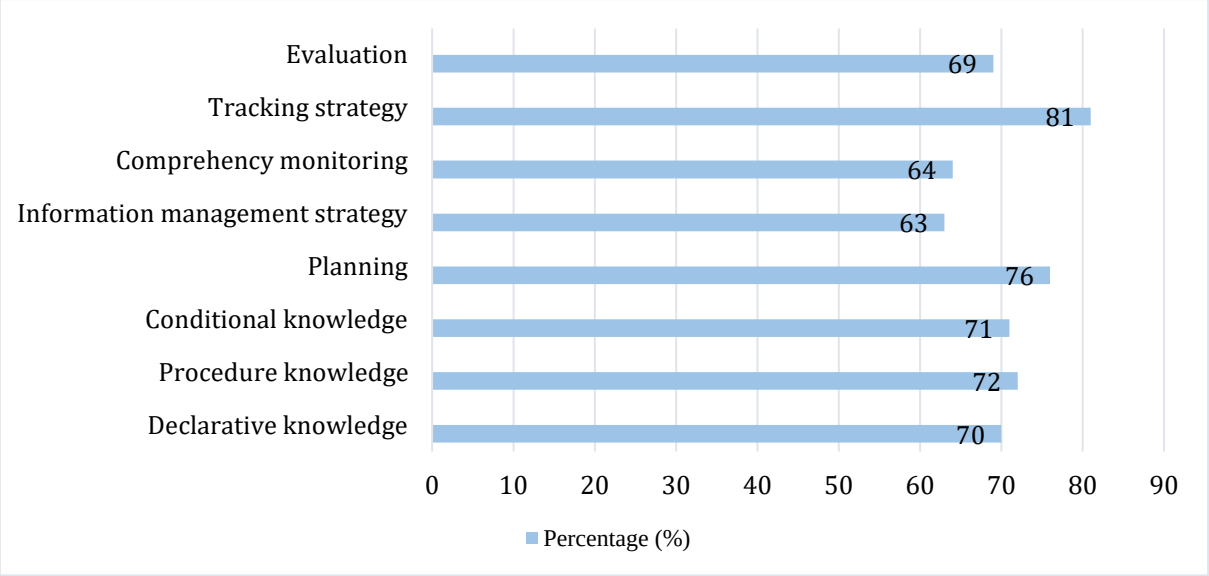

Figure 3. Students' metacognitive awareness

For students to actively apply the metacognitive skills they have gained to aid their learning processes, metacognitive awareness is necessary. Therefore, in this study, completing the metacognitive questionnaire strengthened the assessment of metacognitive abilities through the test. The following are student responses to the metacognitive questionnaire. Figure 3 exhibits the students' responses to the metacognitive questionnaire. The questionnaire used in this study consisted of 52 statements categorized into eight categories: declarative, procedural, conditional, planning, information management strategy, comprehension monitoring, tracking strategy, and evaluation. Figure 3 indicates that the search strategy aspect is the highest level of students' awareness. The need of monitoring knowledge and correcting errors that they or their peers may make while learning starts to sink in for learners. The portion of people who are aware of the information management plan aspect is the smallest. This shows that most pupils do not comprehend the concept and are not accustomed to applying their skills to acquire information more effectively and precisely.

DISCUSSION

Metacognitive ability in learning is an important ability to develop. Metacognitive abilities are considered essential because they relate to how a person carries out the learning process. Metacognitive skills in their implementation can focus learning on students enabling them to learn independently. As Sart (2014) stated, metacognitive abilities will describe how a person can learn independently. The research results show that students' metacognitive abilities still need to be developed. This relates to learning in schools that are still less able to support metacognitive abilities. As stated by Djudin (2017) in his research, many schools still carry out traditional education emphasizing the material and student achievement, not the thinking processes students experience. So according to him, schools need to shift from traditional learning to learning that involves full student activity.

If seen from the results of the work on the metacognitive ability test questions, students generally have an average score. Meanwhile, if you look at the results of calculating the Gain index between pretest and posttest, one could argue that project-based learning in biology classes enhances students' metacognitive skills. Students' ability to follow teacher-given directions in class belongs to poor category when metacognitive strategies have not been developed (pretest). This low metacognitive ability results in low achievement as well (Sart, 2014). This is supported by the findings of Hatami and Moghaddam (2014), that state that strategies that foster metacognitive abilities will impact students' educational progress.

Metacognitive abilities need to be developed with various activities in the classroom. According to Djudin (2017), metacognitive abilities can be developed in activities involving active

students, such as reading, writing, critical thinking, problem solving, thinking in pairs, and reflective learning. According to research, when a teacher incorporates metacognitive skills into classroom instruction, students' learning processes will improve significantly (Dirgantoro, 2018). This is conceivable as a result of the fact that a student's metacognitive approach is always connected to motivation, perceptions, and the classroom instruction style of the teacher (Tian et al., 2018). Project-based learning applied in this study allows for the inculcation of metacognitive strategies in conducting learning. Through project-based learning, teachers' guidance in the classroom and extracurricular discussion activities assist students acquire fresh perspectives on problem-solving (Suseno et al., 2022). They consider the best steps to solve the problem based on the information they gathered during project implementation (Alshammari, 2015) and obtain good learning outcomes (Hakim et al., 2016).

Although according to Ulfiyani (2016) students tend to have limitations in terms of choosing ideas and information when reading a source, they are less able to solve questions that ask them to determine plans for a project. However, teaching it in class will provide a good opportunity for them to learn. Project-based learning allows students to choose learning strategies that suit themselves. Through preparing projects that begin with the questions of what, when, where, and how, students then use the strategies they have set (Rahmawati & Haryani, 2015). During project implementation, especially when they go through the criticism and revision phases, as well as the reflection phase, self-regulated learners occur, so they can assess the use of the strategies they previously determined. This clearly shows a pattern of metacognitive learning that can further strengthen the process of cognition within him. Siegel (2012) said that the metacognitive abilities used to solve problems in learning as stated above, make students successful in the learning process because they use the chosen strategy according to their needs. In the end, the teacher can not only judge their choice of which strategy they use but can also see the differences in the strategy they choose. Students with high metacognitive abilities will determine different strategies from those with low metacognitive abilities (Zhou et al., 2016). Likewise with the results achieved, those with high metacognitive abilities can do something better than those with low metacognitive abilities.

The metacognitive skills developed in the learning process in this study support the hypothesis that these skills are beneficial in fostering students' belief when they independently gain their learning abilities. Along with student-centered learning, learning processes that encourage active involvement of students, such as this project-based learning, are starting to get more attention (Sáiz Manzanares & Martín, 2017). Current studies show that the initiation of metacognitive skills has been carried out from an early age (Sáiz Manzanares & Martín, 2017). For this reason, research on students who are already in middle and high schools needs to be developed further because it has a positive influence on their learning.

In recent years, the involvement of metacognitive components in the accomplishment of cognitive tasks has attracted a lot of research attention. According to researchers, metacognitive ideas, choices, and behaviors affect whether or not people succeed or fail in a number of tasks. However, this ability is often overlooked (Djudin, 2017). They believe that cognitive processes that work well depend not only on the knowledge gained in the learning process but also on awareness and control over that knowledge (Zhao & Mo, 2016). Several studies have also shown the importance of metacognitive abilities in directing the learning process (Sáiz Manzanares & Martin, 2017). According to several research, students' capacity to solve problems and academic achievement both depend heavily on metacognitive awareness (Hatami & Moghaddam, 2014). Metacognitive abilities help students become responsible and independent in self-regulation (Listiana et al., 2016; Sonowal & Kalita, 2017), aware of their learning process (Shank, 2017), more aware and strategic when carrying out the learning process. This ability also allows students to perform self-evaluations accurately when measuring their learning performance (Molenberghs et al., 2016).

In general, the implementation of project-based learning ran well. Students seem more enthusiastic about working on projects when the projects presented provide new information for them. The existence of *Hermetia illucens* larvae which are the medium for decomposing organic waste in this project provides added value for the implementation of learning. This shows that the

results of research in any field can be used as a meaningful learning tool for students. In addition, with the new information they get, the learning process is not monotonous and can grow their curiosity about similar research. However, it should be noted that research using research results related to living things needs to pay attention to several things. One of them is timing. In implementing learning based on the organic waste decomposition project using *Hermetia illucens larvae*, selecting the appropriate phase is the key to the success of the organic waste decomposition project.

With its advantages and disadvantages, the project-based learning carried out in this study has been a good start. This organic waste decomposition learning project is expected to be the foundation for continuing project-based learning using other projects based on the results of research in the field of Biology. It is done as an effort to educate students as part of society about the benefits of biology in everyday life, introduction to biodiversity, and introduction to *insects* and other living things as ecosystem components that we must protect and make the best use of.

CONCLUSION

Project-based learning in Biology has been shown to enhance high school students' metacognitive abilities. The metacognitive ability test results not only show a significant increase in pretest and posttest results but are able to show the distribution of student answer categories on each item. A rise in the categories of students' answers between the pretest and posttest further demonstrate an improvement in students' metacognitive skills. This answer category shows that the students' ability category has shifted from the low category to the medium category, characterized by the dominant Tacit and Aware category at the pretest to the *aware and strategic* category at the posttest. The results of administering the metacognitive questionnaire in this study show that students have the most awareness in the search strategy aspect, demonstrating students' awareness of error correction and tracking students' understanding of learning. Learning based on the decomposition of organic waste projects can be used as a start to present projects raised from the research results in Biology to be used as an alternative to practicum activities on similar materials when the time available is relatively long. This research and learning can also be continued by taking into account several things, including the provision of Black Soldier Fly (BSF) larvae which have the best phases for use in organic waste decomposition projects, project-based learning time adjustments, and identification of students' basic abilities before carrying out project-based learning.

Author contributions

The authors made significant contributions to the study's conception and design. The authors were in charge of data analysis, interpretation, and discussion of results. The final manuscript was read and approved by the authors.

Funding

There was no specific grant for this research from any funding organization in the public, private, or nonprofit sectors.

Conflict of interest

The authors declare that there is no potential conflict of interest.

Data availability statement

All data are available from the authors.

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