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Enhancing students' thinking skills through project-based learning in biology

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ABSTRACT

This research aims to enhance students' thinking skills (TS) through a project-based learning (PBL) intervention in two cycles of classroom action research (CAR) on the topic of the Ecosystem. TS was determined by the quantity and quality of the students' questions (SQ) and statements (SS), which were determined based on Bloom's taxonomy. The research target was students in grade X (N=31) of one social science class at a public high school in Surakarta. Their TS were rated as low during the Pre-cycle. Based on their verbal activities, the students were categorized into five active (A) and non-active (NA) groups (A-1, A-2, NA-1, NA-2, and NA-3). The NA students were more engaged after the two cycles of CAR. Although the A-1 and A-2 students posed more SQ and SS than the NA students, some of the NA-1, NA-2, and NA-3 students performed positively. In the Pre-cycle, only the C1 and C2 cognitive levels were detected, mostly as factual and conceptual. During the CAR, however, C4, C5, and C6 were found as procedural. In Cycle II, we can find a few examples of metacognition. Overall, this research has shown that PBL can be used to increase student learning engagement. They become active communicators. There was evidence that the quality of students' questions and statements improved to the level of C6 and metacognition. Hopefully, further research can be conducted on the impact of grouping strategies during PBL activities by purposively combining high-achieving students or actively questioning and giving their peers statements in the opposite situation.

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INTRODUCTION

Student learning engagement can be assessed via a range of classroom-based activities. One such method is by looking at students' ability to form questions and statements. Questioning is one of the tools that a student has for establishing the truth against an unknown, looking for relationships between events or information, and building knowledge. It has emerged as a form of curiosity (Bowker, 2010; Dkeidek et al., 2011). Meanwhile, a statement comprises a description, explanation, and argument (Spector & Park, 2012) and emerges in response to a question or phenomenon (Braaten & Windschitl, 2011). A statement is a form of communication and is an essential element in the learning of natural science (Kuhn, 2010).

Biology is one of the natural sciences. Natural sciences tend to rely on 'ways of knowing. The student should be positioned as a scientist that construct their knowledge. To construct their knowledge, the role of question and statement or argument is crucial. As long as questions and statements in constructing student knowledge, questions, and statements that students express can be indicated as students' thinking skills (TS) (Widoretno et al., 2016; Ziyaeemehr, 2016). Students' TS can be developed through the learning process at school. Learning that provides the ability to develop critical thinking also enables significant interaction in the classroom (Fuad et al., 2017). Interaction effectively triggers a student to share ideas and construct knowledge (Gillies & Boyle, 2010). The majority of interaction in the classroom is conducted through conversation or communication in questions and statements (Rocca, 2010).

We can assess students' TS through the quantity and quality of their questions and statements (Hofstein et al., 2005). In this research, the quantity is indicated by the students' number of questions and statements. In contrast, the quality is determined by the levels of thinking based on the revised Bloom's taxonomy, while the dimensions of knowledge refer to the table of Anderson & Krathwohl (2001).

Several factors influence students' engagement and TS, including stimulation, the opportunity to ask questions or argue (Chin & Osborne, 2010), the students' initial conceptions (Chin & Osborne, 2008), and the learning method used. Learning methods oriented towards conceptual memorizing and conceptual understanding abilities have not been found to stimulate critical thinking (Snyder & Snyder, 2008). In contrast, however, active inquiry-based learning is capable of stimulating students to ask and argue. Inquiry-based learning activities emphasize students' higher-order thinking skills and students' ability to construct knowledge independently and involve discussion and investigation methods (Pedaste et al., 2015; Saputri et al., 2019). Project-based learning (PBL) is a type of inquiry-based investigative learning that requires a complex thinking ability (Krauss & Boss, 2014). PBL can establish communication, cooperation, and collaboration through discussion and investigation (Capraro et al., 2013).

Topic or learning material also affects students learning engagement in the classroom. Topics related to real issues are suited to improve students' interest in learning biology (Musyaddad & Suyanto, 2019; Trumper, 2006). In this research, the implementation of project-based learning used the Ecosystem topic. Learning Ecosystem through PBL is carried out with investigative activities outside the classroom. Investigative activities outside the classroom increase students' interest in exploring scientific knowledge more widely and are suited to improve students' interaction and development of their higher-order TS (Damșa et al., 2019; Moreira et al., 2018). Students with a high interest in learning will actively participate in the learning activities, which will impact their quantity and quality of the questions and statements (Davies et al., 2013).

The pre-research observation was conducted in the grade X social science class 2 on the Animalia Kingdom to examine the TS of students in terms of their questions and statements. The Animalia Kingdom was the topic before Ecosystem was taught. The Ecosystem was only taught once in senior high school. Therefore, we conducted pre-research observation on

Kingdom Animalia before carrying out our research on Ecosystem. The pre-research observation generally revealed that the learning remained oriented to conceptual understanding and had not advanced to the stage of critical thinking. Communication activities in the classroom were not practical. Students often uttered questions or statements that were not meaningful. Simultaneously, the teacher tended to engage in one-way communication and provided little in the way of opportunity for the students to ask questions or give statements in a way that encouraged them to think more deeply.

The observation results showed that 216 questions were posed during the 3 x 45 minutes on the Animalia Kingdom, mostly representing the C1 and C2 cognitive levels. There were 186 statements, also reflecting the C1 and C2 levels. The dimensions of knowledge were identified to be factual, conceptual, and procedural. Based on these data, student engagement was low, with the students' TS in terms of their questions and statements being classed as lower-order thinking skills (LOTS); as such, improvement is required. Research on TS in terms of posing questions has been carried out, but it used a different learning model, and it is only limited to questions and not statements. In this previous research, the quality of teacher and students' questions expanded into a high level of TS and dimension of knowledge but not metacognitive (Pramudiyanti et al., 2019; Widoretno et al., 2016).

Based on the facts mentioned above, the researchers in this study opted to conduct collaborative classroom action research to improve students' TS in terms of their questions and statements. The researcher focused on NA students through the gradual application of PBL and emphasized activities to provide more opportunities for them to express their opinions. The CAR was conducted on the Ecosystem topic as one of the critical biology areas for grade X students at Indonesian high schools.

METHODS

Research Design

The low TS of the students in the target class required improvement, with classroom action research being one of the recommended approaches for increasing their participation and behavior concerning TS. This type of intervention should be based on inquiry-based learning activity (Pedaste et al., 2015; Saputri et al., 2019). The research team chose to use PBL as an intervention because the students were working on the Ecosystem topic, as the last of the biology topics studied in grade X, and by considering the uniqueness of the Ecosystem concepts that are near related to the students' daily life.

The classroom action research lasted for two cycles to cover the Ecosystem topic in 3 x 45 minutes/cycle. The students' competence to have attained the learning process was analyzing the data and information—the data and information related to Ecosystem topics about the interactions that took place within one Ecosystem. The students were also required to draw all of the ecosystem components' interactions, establish the food web within one Ecosystem, and develop some representations of the food web. The content that the students were required to learn consists of an ecosystem (e.g., a rice field, pond, river, lake, and forest), energy flow, the biogeochemical Cycle, and the interaction between biotic and abiotic components.

Population and Samples

The research was conducted in one public high school in Surakarta, Indonesia. The school is one of the most popular in the city in terms of its student intake, the majority of whom graduate from the best junior high schools in the city, and the students' average scores on the national exam. The school has 11 classes for grade X, three of which are social science classes, and eight are natural science classes. The study of biology is compulsory for grade X. However, students in the social science class are only required to attend three hours of classes per week (a one-hour class equates to 45 minutes of learning time), while the students in the natural science class have four hours of biology lessons a week. One of the social science classes is taught by the teacher, who agreed to participate in this research. The class (N=31) consisted of 21 girls and ten boys, who also voluntarily agreed to join the research.

Instrument and Procedure

The CAR followed the spiral method developed by Kemmis et al. (2014), comprising plan, act, observe, and reflect in each Cycle (Figure.1). Before implementing the action, the preliminary observations to identify the problem were conducted as the reflection phase of the classroom action research. Based on this Pre-cycle data, the students were grouped into two main categories, i.e., active (A) students and non-active (NA) students.

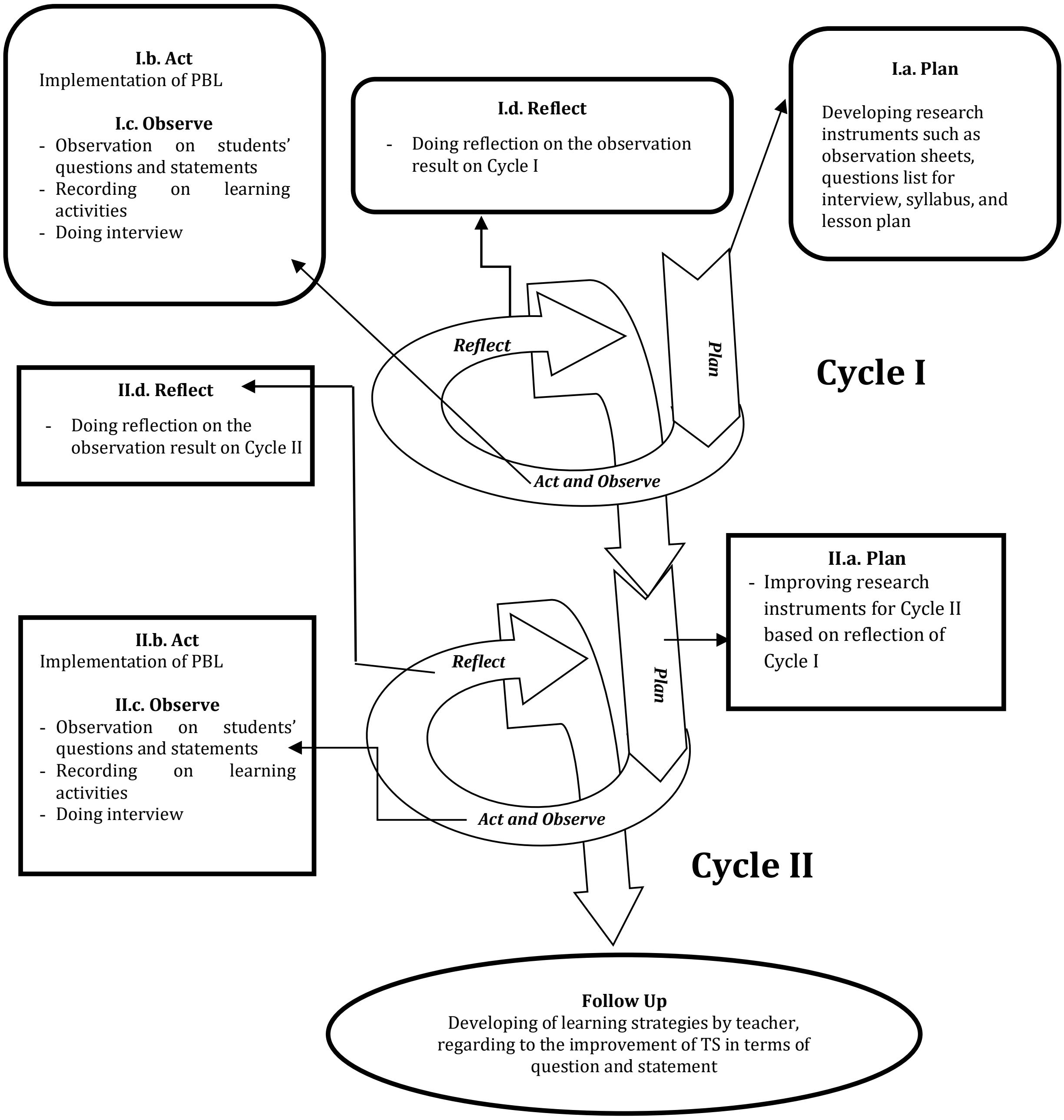


Figure 1. CAR Spiral Method following Kemmis et al. (2014).

The implementation stage consisted of the activities of PBL, data collection, and analysis. The PBL consisted of the following five steps: 1) Planning an investigative process according to driving questions, 2) Searching for the theoretical background of the driving question, 3) Presenting the theoretical background and discussing the issue, 4) Deciding on the study group and the methods for data collection and data analysis, and 5) Evaluating the data, reaching a conclusion, presenting the project in the class as preferred and holding a discussion (Turgut 2008).

In planning an investigation process according to the driving question, the teacher guided students to make an investigation plan that includes determining the tools, materials, and steps of the investigation. Students discussed the investigation in their respective groups. In searching for the theoretical background of the driving question, the teacher guided students to collect theories and information that underlie their investigations. After students found relevant backgrounds and theories through literature reviews, The third step presents a theoretical background to class and discusses the issue. Students presented their investigation plan and the theories underlying their investigation in front of the class. Students carried out question and answer activities. Students completed their investigation plan after getting a suggestion from their friends and teacher. The fourth step is deciding the study group, the way of collecting data, and data analysis. Students conducted an investigation that had been planned. They collected data and analyzed the data. At the end of the fourth step, the teacher assigned students to make a portfolio. The portfolios were collected and presented by each group in the next meeting.

To design the PBL activities, the research team conducted a pilot study comprising a series of lessons with pre-service teacher students, university lecturers, and the biology teachers' association from seven high schools in Surakarta. As part of this process, the lesson plan for the Ecosystem topic was gradually revised to accurately reflect the amount of time allocated to fit in with the school hours. Finally, after some improvements, the female teacher, who was the original teacher of the targeted class, was trained to teach following the lesson plan. The pilot study also included training for the observers who would be conducting the observation during the action research.

The primary data were in the form of the quantity and quality of the SQ and SS. Both counted as data on both class basis and for the individual students, who would later be categorized into active and non-active groups. The primary data for the learning process form of dialogue both between the students and teacher and among the students was comprehensively noted, audio-recorded, and videotaped. Five observers, who were pre-service teachers of biology, conducted the observations and took notes.

Supporting data were also collected in documents related to the students' achievement (namely a formative test on the Virus chapter, alongside midterm and final biology tests). The interview type was conducted with the students and teachers to elicit their responses to the learning process. All of the students' questions and statements during the learning activities were carefully noted and later categorized based on the cognitive level and dimensions of knowledge related to Bloom's taxonomy (Anderson & Krathwohl, 2001).

The interview's objective was to strengthen the observation data regarding the quantity and quality of the students' questions and statements as obtained from the students by the observers during the learning activities. The collected data were subsequently validated using a triangulation method.

Data Analysis Techniques

The data were analyzed descriptively following the analysis model of Miles & Huberman (2012) and thus based on the three activities of data reduction, data presentation, and conclusion or verification. The data reduction was conducted by eliminating the students' questions and irrelevant statements to the learning context.

The first step in the data collection is related to the number of SQ and SS in each Cycle. These data were used to map the changes in the students' TS from the Pre-cycle to the final Cycle. The second step was to analyze the SQ and SS quality by categorizing the data into the dimensions of knowledge and cognitive levels. The four dimensions of knowledge are factual, conceptual, procedural, and metacognitive, while the levels of thinking were grouped into six (C1–C6). A panel discussion, including all the research team members, was chosen to determine the cognitive level and knowledge dimension of the SQ and SS.

The data are presented in tabular and graphical forms that enable a comparison of the quantity and quality of the questions and statements between cycles and compare the changes in the performance of the active and non-active students in each Cycle. Verification was undertaken, and conclusions formed based on the results and data analysis.

RESULTS AND DISCUSSION

In Cycle I, before completing the Ecosystem project activities, the students was invited to think about the interaction between the biotic and abiotic components in one Ecosystem by designing a simple experiment. The teacher prepared fish, hydrilla, 0.05% methylene blue, and four glassware beakers as the materials and tools to be used during the experiment. According to the students' design, the first beaker was filled with 250 ml of water and 0.05% methylene blue. The second contained 250 ml water, 0.05% methylene blue, and single hydrilla. The third was filled with 250 ml water, 0.05% methylene blue, and one fish, while the fourth beaker contained 250 ml water, 0.05% methylene blue, one fish, and one hydrilla. After several minutes, the students observed the changes that occurred in each baker. During the experiment, the teacher asked students to think about what would occur in each beaker if they were covered. The teacher wanted to ask the students to think about the relative states of oxygen and carbon dioxide through this question. The students asked to give their opinions about the relationship between fish and hydrilla. The flow of energy in there and predict the difference in the concentrations of O_2 and CO_2 among the four beakers. The students also asked about biogeochemical processes that might have been taking place in different given situations. After completing the experiment, the teacher asked the students to think about a project to examine the actual situation within a natural ecosystem. The students, as a group, planned a project to investigate the real Ecosystem near their school.

In the second Cycle, the students learned about the different Ecosystem types by continuing with the project activities they had carried out in the first meeting. Before asking them to present their work, the teacher demonstrated a mossy pot containing a plant and an insect. The teacher also provided an old aquarium containing fish, algae, and an aquatic plant. The students were asked to compare the two to form an opinion on the types of Ecosystem. This activity was conducted to introduce students to the various types of Ecosystem and their typical nature and the environment. Later, students were put into groups to discuss the plan for the next project, the primary purpose of studying the types of Ecosystem, the characteristics of each, and how they should be classified.

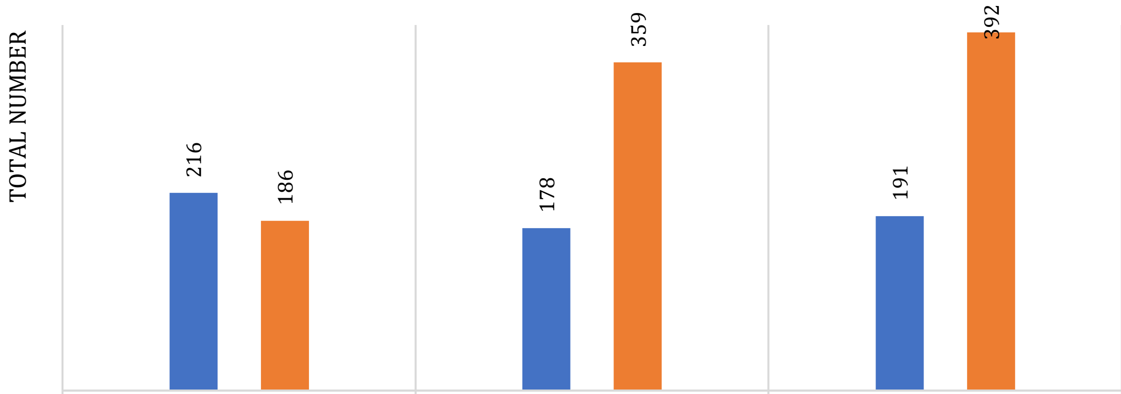
The numbers of SQ and SS recorded during the Pre-cycle, Cycle I, and Cycle II were 402, 537, and 583, respectively. All SQ and SS were organized in a standard order based on the cycle number and phase of PBL, followed by the student's identity (number). The researchers worked together in a discussion to eliminate SQ and SS that did not match the data requirements for this study. The activity was conducted to analyze each SQ and SS's dimension of knowledge and level of thinking.

A comparison of SQ and SS numbers during the Pre-cycle and Cycles I and II are presented in Figure 1. The data in Figure 1 show that although the number of statements in Cycles I and II was higher than during the Pre-cycle, the Pre-cycle trend was for a more significant number of questions. There were 216 SQ in the Pre-cycle, which fell to 178 questions in Cycle I before rising to 191 questions in Cycle II. In contrast, the number of SS increased significantly from the Pre-cycle to Cycles I and II.

The number of SQ fell from the Pre-cycle due to the differences in the number of groups and the length of the learning time allocated. In the Pre-cycle, the students were divided into six groups, whereas in Cycles I and II, they were divided into five groups. Moreover, in the Pre-cycle, discussions were held across 3 x 45 minutes. In contrast, in Cycles I and II, there were two sessions of 45 minutes each on the step of planning an investigative process according to the driving question and searching for the driving question's theoretical background. It has been found that interaction prompts students to share ideas and construct new knowledge (Gillies & Boyle, 2010; Webb, 2009). The majority of students' interaction occurs through conversation or communication; thus, the number of discussion groups and discussion time indirectly affected the number of SQ (Rocca, 2010).

The SS's quantity showed a significant increase from the Pre-cycle to Cycle I and then to Cycle II (Figure 2). It can be argued that PBL activity can stimulate students to provide more statements. This increase may be caused by the scientific investigation that prompted the students to respond to scientific questions or problems by presenting an argument as a statement. Scientific investigation-based learning provides students with opportunities to work on problem-solving by presenting arguments and constructing explanations based on evidence associated with scientific knowledge (Meyer, 2014).

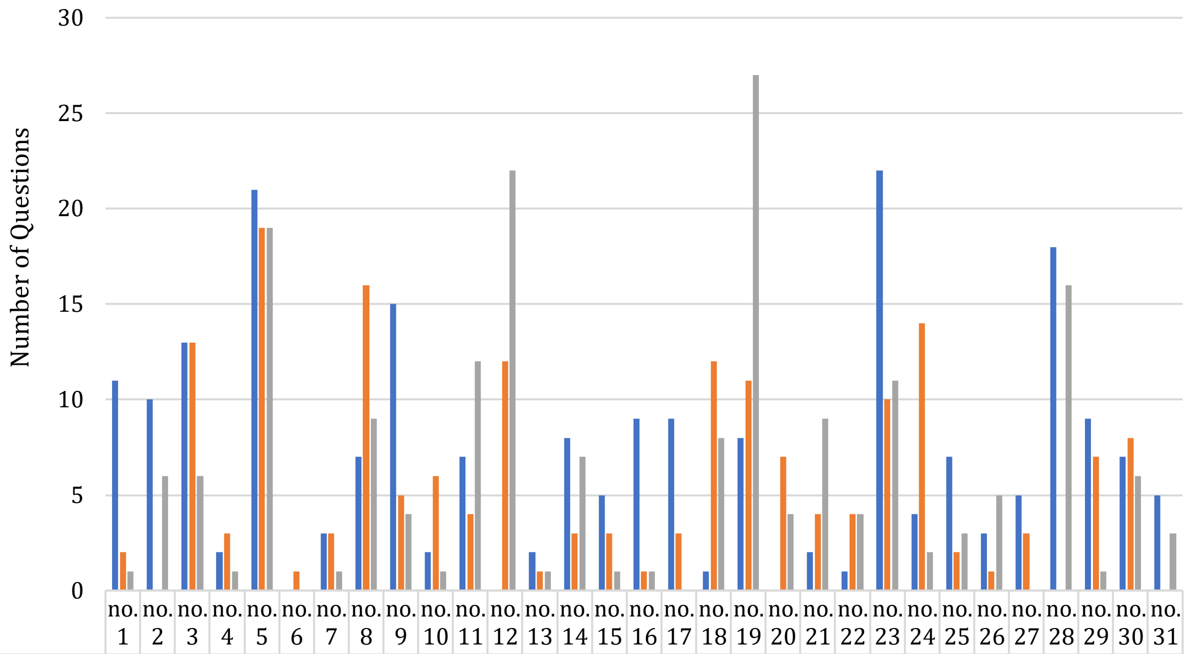
Generally, it can be seen that the students posed more questions than statements during the Pre-cycle period. However, they did the opposite in Cycles I and II, presenting more statements than questions.



	Pre-cycle	Cycle I	Cycle II
Questions	216	178	191
Statements	186	359	392

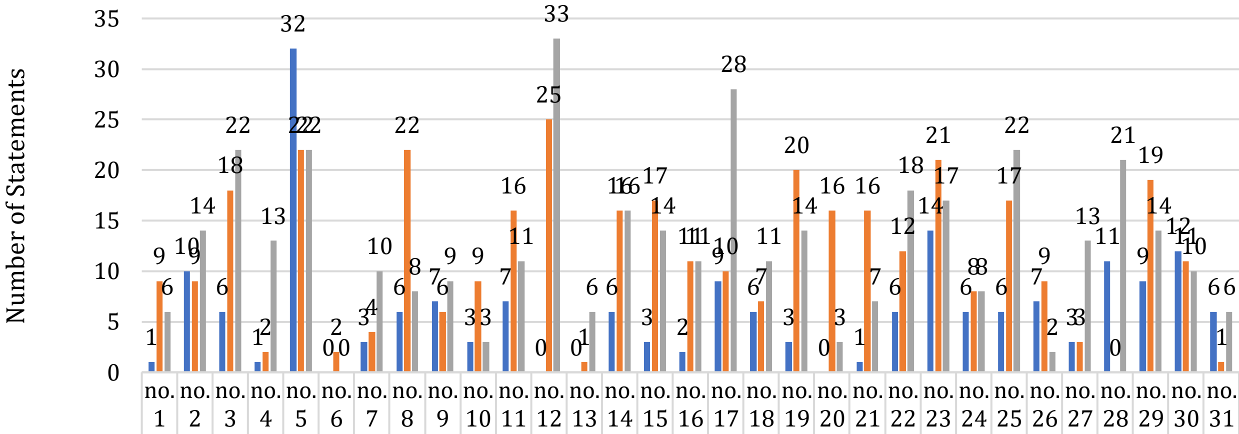
Figure 2. General quantity comparison of the SQ and SS in the Pre-cycle, Cycle I and Cycle II.

Looking at the frequency with which the students asked questions or made statements, we can see that some students remained silent during the learning process, posing zero questions and statements (student nos. 6, 12, and 20) in the Pre-cycle. Others, meanwhile, did pose questions, but less than five (student nos. 2, 7, 10, 13, 18, 21, 22, 24, and 26), and also provided less than five statements (student nos. 1, 4, 7, 10, 15, 16, 19, 21 and 27) in the same Cycle (Fig. 3 and 4). Those non-active students thus have to be guided more carefully than the active students.



	no. 1	no. 2	no. 3	no. 4	no. 5	no. 6	no. 7	no. 8	no. 9	no. 10	no. 11	no. 12	no. 13	no. 14	no. 15	no. 16	no. 17	no. 18	no. 19	no. 20	no. 21	no. 22	no. 23	no. 24	no. 25	no. 26	no. 27	no. 28	no. 29	no. 30	no. 31
Pre- Cycle	11	10	13	2	21	0	3	7	15	2	7	0	2	8	5	9	9	1	8	0	2	1	22	4	7	3	5	18	9	7	5
Cycle I	2	0	13	3	19	1	3	16	5	6	4	12	1	3	3	1	3	12	11	7	4	4	10	14	2	1	3	0	7	8	0
Cycle II	1	6	6	1	19	0	1	9	4	1	12	22	1	7	1	1	0	8	27	4	9	4	11	2	3	5	0	16	1	6	3

Figure 3. Number of questions posed by each student in the Pre-cycle, Cycle I and Cycle II



	no. 1	no. 2	no. 3	no. 4	no. 5	no. 6	no. 7	no. 8	no. 9	no. 10	no. 11	no. 12	no. 13	no. 14	no. 15	no. 16	no. 17	no. 18	no. 19	no. 20	no. 21	no. 22	no. 23	no. 24	no. 25	no. 26	no. 27	no. 28	no. 29	no. 30	no. 31
Pre-Cycle	1	10	6	1	32	0	3	6	7	3	7	0	0	6	3	2	9	6	3	0	1	6	14	6	6	7	3	11	9	12	6
Cycle I	9	9	18	2	22	2	4	22	6	9	16	25	1	16	17	11	10	7	20	16	16	12	21	8	17	9	3	0	19	11	1
Cycle II	6	14	22	13	22	0	10	8	9	3	11	33	6	16	14	11	28	11	14	3	7	18	17	8	22	2	13	21	14	10	6

Figure 4. Number of statements by each student in the Pre-Cycle, Cycle I and Cycle II

Regarding the students' statements during the three cycles, we can discern various patterns (Figure. 4). Student nos. 5 and 23 were consistently active, providing more than ten statements across the three cycles. However, some of the students showed a decrease in the number of statements provided (e.g., student nos. 12, 14, 16). Moreover, student no. 6 was consistently passive during the learning process.

Based on the total number of SQ and SS in the Pre-cycle, the students were categorized into the following five groups: Active 1 (A-1), in which the students provided more than 19 SQ or SS; Active 2 (A-2), with SQ and SS in the range of 10–19; Non-active 1 (NA-1), with the students giving 5–9 SQ and SS; Non-active 2 (NA-2), with 1–4 SQ and SS; and Non-active 3 (NA-3), where the students provided zero questions and statements (Table 1). The targets to be empowered in this action research were those in the NA-1, NA-2, and NA-3 groups.

Table 1
Student activity categories based on the number of SQ and SS in the Pre-Cycle

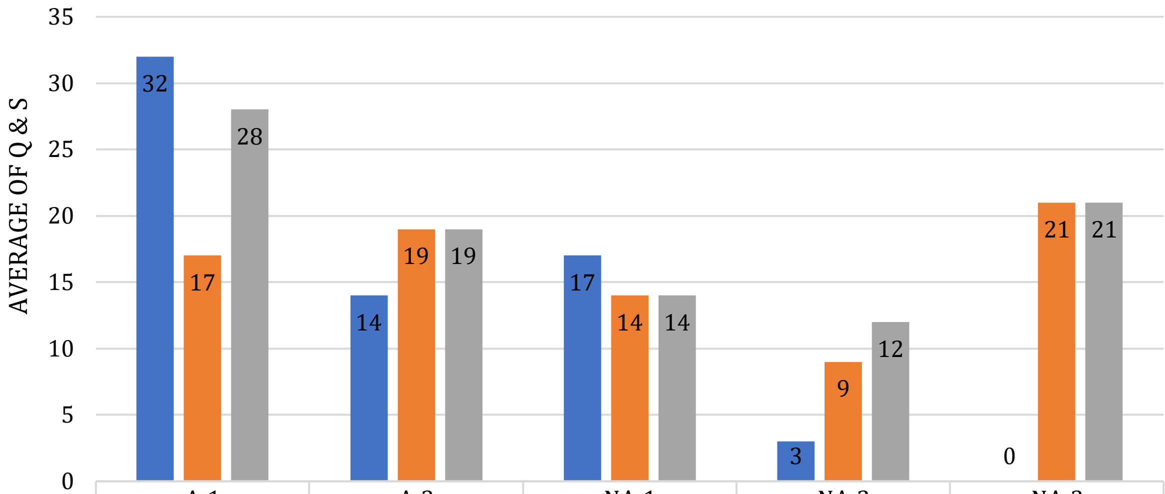
Student Category	SQ & SS	
	Student Nos.	Total (students)
A-1 (Active 1, more than 19 Q & S)	2, 5, 9, 23, 28	5
A-2 (Active 2, 10–19 Q & S)	1, 3, 8, 11, 14, 16, 17, 19, 24, 25, 26, 29, 30, 31	14
NA-1 (Non-active 1, 5–9 Q & S)	7, 10, 15, 18, 22, 27	6
NA-2 (Non-active 2, 1–4 Q & S)	4, 13, 21	3
NA-3 (Non-active 3, zero Q & S)	6, 12, 20	3

The NA-1 and NA-2 students in Cycle I seemed to be more active than in the Pre-cycle. However, student nos. 4 (NA-2) and 6 (NA-3) showed no significant progress across all cycles. There was also inconsistency in terms of the students' engagement in the learning process. Some of the students were very active in the Pre-cycle but proceeded to display a different attitude in Cycle I and II (student nos. 1 and 2). Another type of students displayed progressive activity, from zero questions in the Pre-cycle to more than ten over the next two cycles (student no.12 from NA-3). Furthermore, two students performed at a consistently high level by posing more than ten questions and statements across all three cycles (student nos. 5 and 23).

Each group's general changes can be determined by calculating the total and average numbers of SQ and SS in each Cycle. Figure 4 summarises the improving trend of SQ and SS during the three cycles. It can be noted that the A-1 students performed well, maintaining a high number of questions and statements. Assuming that there are two 45-minute learning periods per Cycle, there could have been around 22 SQ and SS in the Pre-cycle (there were 32 SQ and SS from the A-1 students for the 3 x 45 minutes in the Pre-cycle). Despite some fluctuation in the number of SQ and SS from the A-1 group, they consistently provided more than ten. There was an increase in the number of SQ and SS for the A-2 group. Using the same assumption as applied for A-1, there should have been around four SQ and SS for A-2 in the Pre-cycle. However, there was no improvement in the quantity of SQ and SS between Cycles I and II, indicating that the A-2 students had a more stable performance or no significant improvement (Figure. 5).

A similar situation can be seen for the NA-1 group, in which the students showed no change during the phases of action research (Cycles I and II). However, the NA-2 and NA-3 groups' students performed significantly different between the Pre-Cycle and Cycles I and II. The NA-2 group comprised three students, and they performed well in Cycles I and II. The NA-3 students contributed the same number of SQ and SS in Cycles I and II, totaling over 20 per Cycle. However, if we check each student's detailed contributions in NA-3, it was the only student no. 12 who supported the improvement, with students nos. 6 and 20 not contributing as much.

The trends seen among the NA students demonstrate that those students with low achievement or low performance will gradually respond better as they discover new experiences of learning through the project activities. The students in these groups may begin to feel comfortable due to adequate opportunities to explore their thinking. In previous or regular learning sessions, some of the students could not express their opinions due to a lack of opportunities for them to communicate. In contrast, other students were overly talkative and tended to dominate the conversation in the classroom. In other words, there was unequal access to communicate for all students in the normal learning process. In contrast, however, using a PBL approach, the teacher had systematically arranged the classroom to provide more access and opportunities for non-active students. They sometimes felt shy and reluctant to communicate.



	A-1	A-2	NA-1	NA-2	NA-3
Pre-cycle	32	14	17	3	0
Cycle I	17	19	14	9	21
Cycle II	28	19	14	12	21

Figure 5. Students categories based on the number of questions and statements A-1: Active 1 (more than 19 SQ & SS in the Pre-cycle); A-2: Active 2 (10–19 SQ & SS in the Pre-cycle); NA-1: Non-active 1 (5–9 SQ & SS in the Pre-cycle); NA-2: Non-active 2 (1–4 SQ & SS in the Pre-cycle), and NA-3: Non-active 3 (zero SQ & SS in the Pre-cycle)

If we look at each student's detailed change, we grouped the students into seven groups, denoted P1–P7 (Table 2). Based on the quantitative data for the questions and statements, we have the following patterns of student participation: consistently posed more than ten questions in all cycles (P1); increased the number of questions but less than ten in total (P2); increased the number of questions and up to ten (P3); fluctuated and up to ten (P4); fluctuated but less than ten (P5); consistently decreased (P6), and consistently posed less than four questions (P7) (Table 2).

It can be seen that student no. 5 performed well for both questions and statements (P1 category), along with student no. 23. The students in the P1, P2, P3, and P4 categories showed positive responses to the learning process. However, the groups of students that were continuously passive (P7), who showed a decrease in the number of questions and statements (P6) and whose number of questions and statements fluctuated but remained less than ten (P5), require both a different and more intensive approach.

Instead of merely following the PBL routine, there should also be serious consideration given to the management of the groups of students, such as the setting of groups based on the students' achievement or level of activeness. Students' grouping cannot simply be randomised to form a heterogeneous group; instead, the groups should be mixed and comprise students from both the active and non-active categories. Grouping strategies are very influential in the successful implementation of inquiry-based learning, especially on the effectiveness of the students' interaction during doing their investigation (Asyari et al., 2016; Nhan & Nhan, 2019; Skinner et al., 2015)Several different factors may contribute to students remaining passive. These include them not being engaged in the subtopics being studied; having difficulty adapting to the learning activities; the teaching style not matching the students' learning style; unequal distribution of opportunities among students to pose questions and give statements; and various internal factors of the students that have been expressed strongly during the lesson (Barlow & Brown, 2020; Williams et al., 2018).

Table 2
The pattern of students' participation based on the number of questions and statements in the three cycles

Category of Participation	Data on Students' Questions		Data on Students' Statements	
	Student no.	∑ students	Student no.	∑ students
P1. Consistently high (more than 10 in all cycles)	5	1	5, 23	2
P2. Increased up to 10	12, 19, 23, 29	4	12, 14, 16, 18, 22, 25, 27	7
P3. Increased but less than 10	21, 22	2	3, 4, 7, 13, 19, 24	6
P4. Fluctuated and up to 10	8, 11, 24, 28	4	2, 8, 11, 15, 20, 21, 28, 29	8
P5. Fluctuated but less than 10	26, 30, 31, 2, 10, 14, 18, 20	8	1, 9, 10, 26, 31	5
P6. Consistently decreased	1, 3, 9, 15, 16, 17, 25, 27	8	30	1
P7. Consistently low (less than 4)	4, 6, 7, 13	4	6	1

The SQ and SS quality, based on the dimensions of knowledge in each Cycle, can be seen in Figure 6. It can be seen that there were fluctuations in the quality of the SQ and SS for the factual and conceptual dimensions.

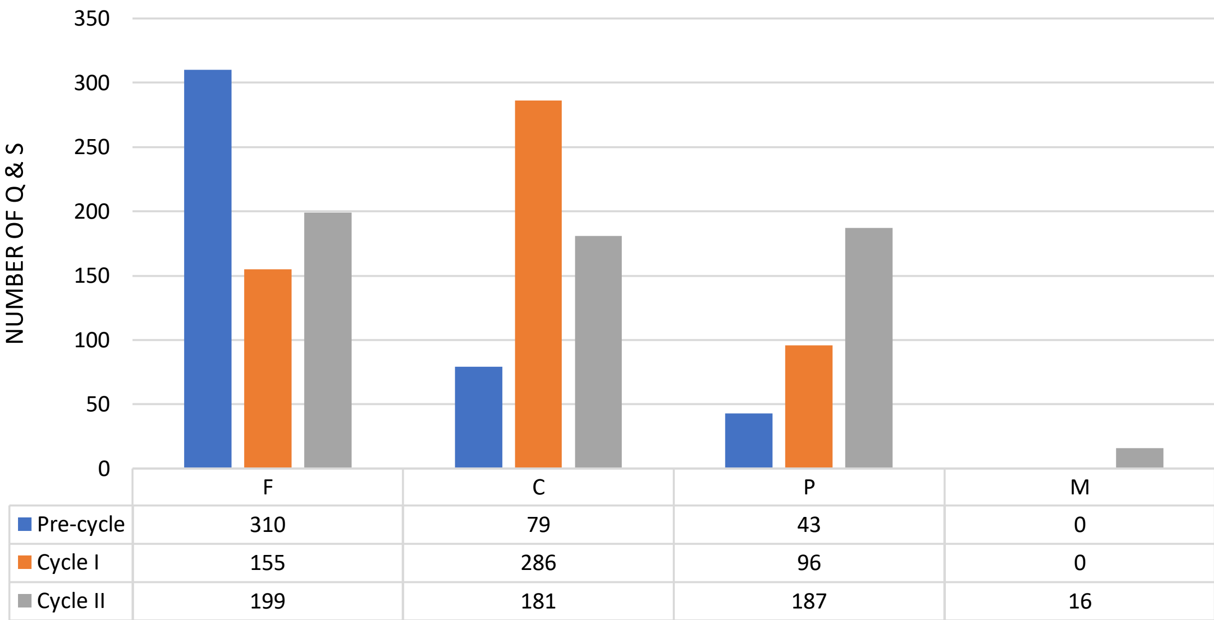
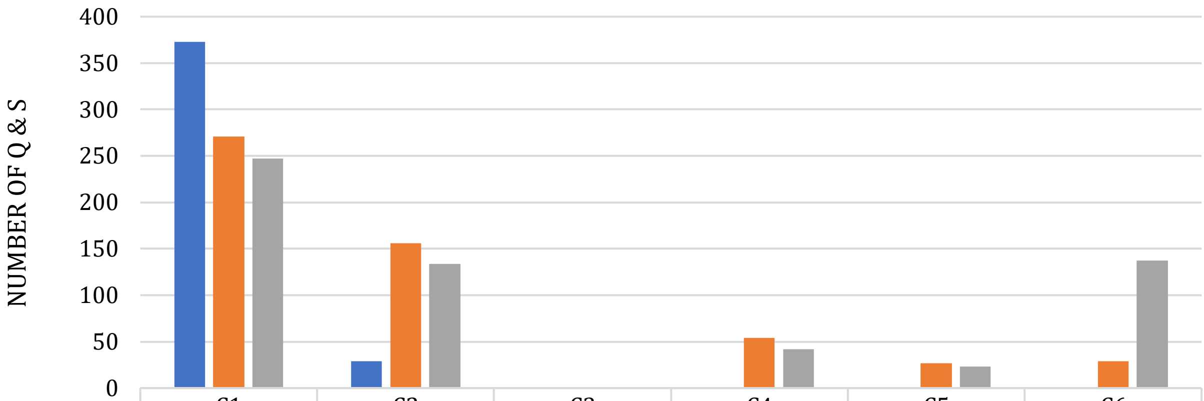


Figure 6. Comparison of the quality of SQ and SS based on dimensions of knowledge: F = factual, C = conceptual, P = procedural, and M = metacognitive

Concerning the factual dimension, 310 SQ and SS were recorded for the Pre-cycle, falling to 155 in Cycle I and then increasing to 199 in Cycle II. On the conceptual dimension, the highest number of SQ and SS were found in Cycle I, with 286, while the lowest 79 were found in the Pre-cycle. The number of SQ and SS on the procedural dimension showed a significant increase between the Pre-cycle and Cycle II, with 43 SQ and SS recorded in the Pre-cycle, rising to 96 in Cycle I and reaching 187 in Cycle II. In respect of the metacognitive dimension, SQ and SS were found only in Cycle II, with a total of 16.

Figure 7 shows the SQ and SS quality based on the level of thinking in the Pre-cycle, Cycle I, and Cycle II. The questions and statements in the Pre-cycle were on the C1 and C2 levels only. They were thus indicating the LOTS of the students at this stage. During the Pre-cycle, the students posed questions and statements in the factual, conceptual, and procedural dimensions only on the level of remembering or understanding.



	C1	C2	C3	C4	C5	C6
Pre-cycle	373	29	0	0	0	0
Cycle I	271	156	0	54	27	29
Cycle II	247	134	0	42	23	137

Figure 7. Comparison of the quality of the students' statements based on cognitive level: C1 = recalling, C2 = understanding, C3 = applying, C4 = analysing, C5 = evaluating, C6 = creating

The number of SQ and SS categorized as C1 fell towards the end of the action research. In contrast, the number of SQ and SS in C2 fluctuated from the Pre-cycle to the next two cycles. No SQ and SS at the C3 level was recorded across any of the cycles. The few SQ and SS detected as C4 and C5 were found in Cycles I and II. However, the SQ and SS indicating the C1, C2, and C5 levels typical of metacognition were found only in Cycle II.

Based on the learning dimension, the SQ and SS quality posed by the NA-1, NA-2, and NA-3 students were mostly factual and conceptual. In contrast, several students posed SQ and SS in the procedural and metacognitive dimensions, such as students nos. 7 and 12. Regarding the cognitive level, some of the NA groups posed SQ and SS that demonstrated progress towards the higher levels. Student nos. 12 and 27 achieved C4, C5, and C6 (the respective data have not been included).

Some examples of the SQ and SS posed in Cycles I and II are presented in Table 3. The factual questions and statements relating to the facts and real situations that the students observed during the project-based activities, including: 'Are there insects in the sewer ecosystem?'; and 'the animal found in the garden ecosystem is not a millipede, but it is a worm.' Conceptual SQ and SS represent the concept, principles, theory, and generalization connected to the Ecosystem, such as: 'Are interactions between plants and sunlight categorized as commensalism?' The procedural aspect describes the methodology, procedure, and strategy. The following SQ and SS indicate the procedural dimension: *'The experimental design was carried out by inserting 250 ml of methylene blue solution in each bottle', and 'It is better to look for relevant theories in advance.' The metacognitive dimension of knowledge was the least* *identified in this research*. The following statements are examples of metacognition: *"Based on my personal experience when I was fishing, there were shrimps in the river indeed, but they are not like the shrimps found in the sea; the river shrimp have a colour similar to river water – somehow they can camouflage"* and *"What are the planned stages after analysing the data and then making the report correct?"*

Table 3
Examples of SQ and SS based on dimension of knowledge and cognitive level

Dimension of knowledge	**Cognitive level**	**Student Question & Statement**
Factual	C1	Are the plants in the pond called taro? (Cycle I, Std. 8, Phase 4, SQ 112) Is there any competition in the sewer ecosystem? (Cycle I, Std. 14, Phase 5, SQ 172)
	C2	Are there insects in the sewer ecosystem? (Cycle I, Std. 19, Phase 1, SQ 50) What are the purposes of conducting sampling? (Cycle I, Std. 5, Phase 3, SQ 106). What interactions occur in the sewer ecosystem? (Cycle I, Std. 19, Phase 4, SQ 136)
	C3	Not available
	C4	Is that plant a kind of banyan tree because it has a breathing root? (Cycle I, Std. 29, Phase 4, SQ 148) The interaction that occurs in bottle 4 is that fish use O2 from plants and plants use CO2 from fish (Cycle I, Std. 12, SS 13, Phase 1) A bird's nest is not an ecosystem. There is no interaction in an aviary, there are only birds in it (cycle I, Std. 3, SS27, Phase 1)
	C5	There were grasshoppers in our previous prediction; apparently, there are no grasshoppers in the garden ecosystem (Cycle I, Std. no 11, SS189, Phase 4) The animal found in the garden ecosystem is not a millipede, but it is a worm (Cycle I, Std. 12, SS 231, Phase 4)
	C6	Are any tools needed for investigation other than stationery and cameras? Cycle I, Std. 5, SQ11, Phase 1) The research problem is 'is there a relationship between the constituent components of the ecosystem?' (Cycle I, Std. 12, SQ19, Phase 1)
Conceptual	C1	How do living / non-living creatures interact with fish? (Cycle I, Std. no. 8, SQ13) Are interactions between plants and sunlight categorised as commensalism? (Cycle I, Std. 30, SQ19, Phase 1)
	C2	What types of interaction occur in a pond? (Cycle I, Std. 30, SQ 21, phase 1) Is the interaction in the pond harmful? (Cycle I, Std. 5, SQ23, phase 1)
	C3	Not available
	C4	Does the bottle containing fish and plants develop a cleaner solution? (Cycle I, Std.19, SQ41, phase 1) Plants carry out respiration, therefore they emit CO2 (Cycle I, Std. 29, SS)
	C5	Does sampling damage the ecosystem? (Cycle I, Std. 5, SQ107, phase 3)

		Symbiosis is a form of interaction between living things and other living things, and land is not a living thing (Cycle I, Std. 2, SS76, phase 1)
	C6	What is the relationship between the components of the ecosystem? (Cycle I, Std. 19, SQ42, Phase 1) Air is an abiotic chemical component because there is O2 and CO2 in the air (Cycle I, Std. 25, SS154, phase 3)
Procedural	C1	Should we observe the food web? (Cycle I, Std. 11, SQ 36, phase 1) Is an explanation of a theoretical framework written in paragraph form? (Cycle I, Std. 20, SQ99, phase 2) It is better to look for relevant theories in advance (Cycle I, Std. 4, SS145, phase 2)
	C2	How is data analysis done? (Cycle I, Std. 29, SQ86, phase 1) Should the interactions observed be specific? (Cycle I, Std. no. 12, SQ71, phase 1) Data analysis was written after returning from the field (Cycle I, Std. 8, SQ 33, phase 1)
	C3	Not available
	C4	Plankton was not observed because it was not visible (Cycle I, Std. 14, SS 38, phase 1)
	C5	The relationship that should be searched for, as mentioned in the Student Worksheet, is the relationship between components of the ecosystem rather than symbiosis (cycle I, Std. 2, SS 77, phase 1) Data analysis aims to answer the problem statement, so we have to go to the field in advance (Cycle I, Std. 30, SS 51, phase 1) Why is the interaction observed commensalism and mutualism, not the relationship between biotic and abiotic? (Cycle I, Std. 20, SQ 40, phase 1)
	C6	The experimental design was carried out by inserting 250 ml of methylene blue solution in each bottle (Cycle I, Std. 5, SS 105, phase 1) What are the steps of the investigation carried out? (Cycle I, Std. 21, SQ 38, phase 1)
Metacognitive	C1	The planned activities should be written before going to the location and making observations (Cycle II, Std. 7, SS 162, phase 1)
	C2	How do you analyse if no data has been obtained? (Cycle II, Std. 5, SQ 26, phase 1) Analysis of data is based on the results or data obtained during the investigation (Cycle II, Std. 5, SS74, phase 1)
	C3	Not available
	C4	Not available
	C5	What are the planned stages after analysing the data and then making the report correct? (Cycle II, Std. 19, SQ 133, phase 1) Based on my personal experience when I was fishing, there were shrimps in the river indeed, but they were not like the shrimps found in the sea; the river shrimp have a colour similar to river water – somehow they can camouflage (Cycle II, Std no. 17, SS 335, phase 5)
	C6	Not available

There was a significant increase in the number of SQ and SS during the two cycles of classroom action research if we assume an equal number of learning periods in each Cycle. Those students with a range of abilities demonstrated various patterns of posing questions or expressing statements. However, there was also a consistent pattern of a few active students performing well across all cycles. Meanwhile, it was also detected that the non-active students permanently showed a significantly low performance, but there was also a trend for improving. Other students, meanwhile, fluctuated in terms of their performances. This situation may have been caused by the PBL activity intervention, in which students were accorded adequate opportunity to challenge their TS. The experiment that the students conducted in the first Cycle provided them with opportunities to question or state more than the traditional types of activities commonly delivered by the teacher. The planning, designing, and conducting of a project provided the students with many opportunities to share their opinion.

The more significant increase in the number of SS compared to SQ in the two action cycles may have been due to the types of activities typically carried out during the action research. A student might express a statement for many different reasons, such as to answer the question posed to them by the teacher or to counter a peer's opinion. However, students' questions will emerge in response to a request by the teacher to pose questions, with the students expressing their opinion based on the different facts they have discovered, and probably also due to their own innate need to discover new things. However, the latter is not common among Indonesian students. Generally, it may be stated that posing questions requires extra effort and an appropriate boost compared to giving a statement.

The quality of students' questions and statements on the implementation of PBL showed an overall increase compared to the Pre-cycle. Based on the level of thinking, the students' questions and statements' quality was more widely distributed. In the Pre-cycle, there was a distribution across only in C1 and C2 levels. In the Cycles, I and II were extended to C1, C2, C4, C5, and C6 levels. Some of the students could ask questions and give statements at the higher-level TS (C4, C5, and C6). However, overall, the students' questions and statements remained at the C1 and C2 levels. There were no student questions and statements at the C3 level. PBL is thought to be less sensitive to efforts to train and improve questions and statements at the C3 level. However, it may have been possible to identify SQ and SS at the C3 level had the action research been implemented across more than two cycles. Further research needs to be conducted regarding the sensitivity of the model or the effect of PBL implementation on students' questions and statements at the C3 level.

The students' questions and statements showed an overall increase in the factual, conceptual, and procedural dimensions compared to the Pre-cycle based on the dimensions of knowledge. The quality of the questions and statements on the metacognitive dimension appeared in Cycle II, although in a small quantity. Metacognition is defined as 'thinking about your thinking', which involves self-awareness and control of cognitive processes (Seraphin & Philippoff, 2012). The learning design applied significantly affects metacognitive skills (Cicek & Tok, 2014). Compared to cooperative training-by improving, project-based activities are thought to be less suited to improvements in metacognitive skills (Jayapabra, G., & Kanmani, 2013). A cooperative learning model allows students to interact intensively, and un model's sensitivity is solving the problem at hand (Jayapraba, 2013).

Factors that affect the quantity and quality of the students' questions and statements include stimulation, the opportunity to ask or argue (Chin & Osborne, 2010), the initial conceptions held by the students (Chin & Osborne, 2008), and the lesson topic (Trumper, 2006). The stimulation and opportunity to ask or argue relate to the learning model applied in the class. Learning activities can stimulate students to ask and argue, constitute active learning, and fall within an inquiry-based model.

PBL is a form of inquiry-based learning. PBL can establish communication, cooperation, and collaboration through discussion and investigation (Capraro et al., 2013). There are five steps concerning the PBL model: 1) planning an investigative process according to the driving question, 2) searching for the theoretical background of the driving question, 3) presenting the theoretical background to the class and discussion about the issue, 4) determining the study group and methods for the collection and analysis of data, and 5) evaluating the data, reaching a conclusion, presenting the project in class as preferred, and discussion (Turgut, 2008).

Each student has different initial conceptions, and these differences lead to the difference between the quantity and quality of the questions and statements put forward (Chin & Osborne, 2008). Students with a good foundation of initial conceptions are more prepared to learn effectively; thus, they can pose more questions and articulate more statements. During the implementation of PBL within the target class, the teacher-led the apperception by linking the students' initial conceptions to the new concepts to be learned. The students were expected to ask more questions and give more statements during the investigative process following the teacher's work on strengthening the concepts through the apperception activities.

The lesson topic may affect the students' interest in becoming active learners. Topics that can be related to students' personal lives and personal needs are suited to stimulating students' interest in learning biology (Trumper, 2006). The topic of the Ecosystem that was learned about during the action research was capable of arousing the students' interest since it touched on some of the daily issues they encountered. The learning for the ecosystem topic through PBL incorporated the conducting of investigative activities outside the classroom. Investigative activities outside the classroom increase students' interest in exploring scientific knowledge more widely and are suited to higher-order TS development. Students with a high interest in learning will actively participate in the learning activities, which will automatically impact the quantity and quality of the questions and statements that they share (Davies et al.,2013).

The quantity and quality of SQ and SS during the implementation of PBL are associated with their average scores on various tests (taken before the implementation). These were carried out to determine the influence of the students' initial conceptions on the questions and statements they gave. Average test scores were based on the daily Virus chapter tests, the midterm test, and the final biology test. The tests' average score revealed no correlation with the quantity and quality of the students' questions and statements during the implementation.

The student with the highest average score in the tests, student no. 29, did not show any significant differences in asking questions and giving statements during the learning process. This data compares to the student no. 11, who had the lowest average score on the tests. During the implementation, those students with scores approaching the average for the class asked questions and gave statements that displayed wide fluctuation in terms of their quantity or quality. The correlation between students' achievements after the intervention and the quantity and quality of their questions and statements needs to be studied further by analyzing students' learning achievements before the intervention, which should then be correlated with the SQ and SS during the intervention. The form of the tests and the test items used to evaluate students' learning achievements need to be analyzed and adapted according to their needs and oriented to develop critical thinking.

Time limitation became an obstacle in the implementation of PBL. During the presentation of the students' investigation, students could not have a more in-depth discussion. There should be opportunities throughout the project and presentation time to get students to think deeper about their investigation (Edmunds et al., 2017). Another obstacle encountered is that there are students who still tend to be passive. The teacher should take the initiative to provide these less active students opportunities to state questions and opinions. Further research needs to be conducted with more consideration of time management for each Cycle, especially on the step that can raise critical questions and statements.

CONCLUSION

Based on the results and discussion above, it can be concluded that the PBL intervention for the topic of the Ecosystem led to a significant improvement in the students' questions and statements. PBL was shown to be capable of maintaining a high quantity of questions and increased the number of statements seen in all of the cycles of action. In Cycles I and II, the quality of the students' questions and statements was an increase, and these were variously shared. The data revealed a more broad distribution of questions and statements from C1 to C6 in conceptual and procedural dimensions. Questions and statements in the metacognitive dimension appeared only in Cycle II and in only a limited quantity. It can be stated that the PBL intervention in the two cycles of action research resulted in no significant impact on the level of metacognition. However, it may be possible to see this effect with a more significant number of cycles. Research on students' TS in terms of questions and statements is rarely found. Previous research mainly focused on one variable, limited to question or only statement (argument) (Chin & Osborne, 2010; Pramudiyanti et al., 2019; Widoretno et al., 2016). Indeed, the application of PBL has been frequently conducted in CAR but not directly link to questions and statements. The results of this research can be used as a reference for other CAR regarding students' TS in terms of questions and statements. This research also provides a useful reference for correlating TS with questions and statements and provides a comprehensive discussion on each Cycle and each individual. Further research should be carried out on the impact of grouping strategies during PBL activities by purposively combining high-achieving students or those who actively question and give statements, with their peers in the opposite situation, to work as the members of one investigation group. Several tests can also be applied to students before and after the implementation of PBL. These tests could powerfully support the correlation of SQ and SS with TS.

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