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Promoting students' metacognitive awareness and cognitive learning outcomes in science education

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ABSTRACT

This research aimed to investigate the effect of project-based learning (PjBL), predict-observe-explain (POE), and predict-observe-explain based project (POEP) on metacognitive awareness and cognitive learning outcomes in biology learning. The research used a pretest-posttest non-equivalent control group design. The experiment was conducted from August to December 2020. The metacognitive awareness questionnaire was applied to measure students' metacognitive awareness. Besides, an essay test was used to assess cognitive learning outcomes. Data collection in this study was carried out using Google Form, Google Classroom, Google Meet, and WhatsApp. Data analysis using statistical product and service solutions (SPSS) version 23 software. The analysis of covariance (ANCOVA) results analysis showed that PjBL, POE, and POEP affected students' metacognitive awareness and cognitive learning outcomes in biology learning with a value of p<0.005. The least significant different (LSD) result was significantly different in improving students' metacognitive awareness and cognitive learning outcomes. The POEP class gained the highest posttest score. Therefore, POEP could be applicable to improve students' metacognitive awareness and cognitive learning outcomes in Biology learning.

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1. INTRODUCTION

The 21st century presents a complex challenge from the sides of life. Thinking skills are required to succeed in the era of globalization. One of the skills is metacognitive awareness. Metacognitive awareness has been recognized since 1970 by cognitive psychology. Metacognitive awareness means thinking about one's own thoughts [1]. Metacognitive awareness is essential for students to solve life problems [2]. Metacognitive skills assist students in achieving success in the future [3]. Students are expected to do regulation in thinking [4]. Empowering metacognitive awareness in learning habituates students to become independent learners [5]. Metacognitive awareness is the ability to be aware of what is known and how to use knowledge [6]. Metacognitive awareness consists of declarative knowledge, procedural knowledge, conditional knowledge, planning, information management strategies, monitoring, problem-solving strategies, and evaluation [7]. Learning activity that empowers metacognition is indispensable to develop an excellent problem-solving capacity [8].

Unfortunately, current learning is not fully empowering students' metacognitive awareness [9], [10]. In general, classroom learning uses conventional learning, which does not facilitate students to develop metacognitive awareness [11]. The survey conducted in biology learning on high school in Indonesia indicated the necessity of students' metacognitive awareness development. It was mainly in planning, information management strategy, monitoring, problem-solving, and evaluating.

The results of a survey conducted on high school students in the city of Tarakan, Indonesia (January, 2020) showed that in the planning aspect was 66.28% in the developing category. It means that students were unable to ask themselves questions about the material before starting learning; not thinking about what to learn before starting the lesson; and does not measure the time to achieve goals in learning. Aspects of student information strategy management with 58.67% in the developing category, meaning that students are not able to make pictures or diagrams to help learn a topic and are not consciously focused when finding important information. The monitoring aspect with 59.42% in the developing category, means that students do not ask themselves about the consideration of options when solving problems, students do not consciously analyze the usefulness of strategies used in learning, and students do not ask themselves about how good they are in learning something new. Aspects of problem solving with 59.73% in the developing category, students do not change strategies when they fail to understand a material. The evaluation aspect with 57.67% in the developing category, students did not ask themselves whether they had learned a lot to complete the task.

Students' metacognitive awareness needs to be improved in learning to make it easier for students to learn. This is consistent with the results of research conducted by Choy *et al*. [12] which states that student learning skills are part of metacognitive awareness. The results of the analysis show that metacognitive awareness has an effect on cognitive abilities [12]. The results of a similar study were also conveyed by Kramarski *et al.* [13] that students in the cooperative learning class with metacognitive instruction had better cognitive learning outcomes than the cooperative learning class without metacognitive instruction. Rhodes [14] added that metacognitive awareness is used to monitor a person's cognitive ability to think.

Cognitive learning outcomes consist of remembering, understanding, applying, analyzing, evaluating, and creating [15]. It is often referred to as concept mastery which could be defined as the relationship between concepts demonstrated and used to solve everyday life problems [2], [15]. Cognitive learning outcomes in science learning that play a role in character messages, and students' habituation to be skilled in thinking [16]. In addition, cognitive learning outcomes are a standard of product and product to the development of a learning [17]. Cognitive skills should emphasize thinking, using learned knowledge, presenting in one's own words, finding analogies, and creating ideas. If fulfilled, students can internalize and reflect on the concept and master the concept comprehensively.

The cognitive learning outcomes in scientific learning are currently limited in the aspect of remembering, understanding, and applying [18], [19]. A survey conducted in high school in Tarakan, Indonesia, in January, 2020, discovered the percentage of students' cognitive skills. The aspect of remembering and understanding gained 88.45% and 81.28%, respectively. Both numbers fall in the good category. The aspect of applying gained 61.24%, which is in the fair category. The aspect of analyzing, evaluating, and creating gained 23.50%, 9.69%, and 36.97%, respectively, which are in the poor category. The results indicate that the development of higher dimension cognitive skills is required.

Observation conducted on the implementation of science learning at school showed that conventional learning methods, such as answering questions in the student worksheet, were applied. The students were asked to answer the questions where the answers were available in the book. Such a learning activity does not facilitate the students to think profoundly. A proper support system is required to empower higher-order thinking skills, such as suitable learning models and adequate facilities. Students' cognitive skills can be developed through active learning.

Active learning carried out consistently could help the student understand the concept in depth [20], [21]. The predict-observe-explain (POE) and project-based learning (PjBL) are constructivist learning models that actively involve students. POE emphasizes the conceptual aspect [22]. An experimental study at Recto Memorial National High School in the Philippines discovered that students' cognition regulation was less optimal during POE learning [23]. POE learning did not affect students' metacognitive awareness empowerment [24]. Students have not been able to make relevant predictions [25]. To overcome these weaknesses, the research integrates POE and PjBL into predict-observe-explain based project (POEP).

POEP is expected to empower metacognitive awareness and improve cognitive learning outcomes. PjBL emphasizes cognitive learning outcomes and more on 21st century metacognition skills [26]–[28]. POEP learning could mutually reinforce the empowerment of students' metacognition and cognition in learning, especially in science learning. Metacognition awareness is substantial for students in science learning [29], and a conceptual understanding of science is essential as a provision for life [30].

During the COVID-19 pandemic, The United Nations Educational, Scientific and Cultural Organization urges all countries affected by COVID-19 to change the learning system to cut off the spread of the corona virus. The Indonesian government also requires online learning implementation. Therefore, the implementation of POEP learning for this research would be conducted online. POEP learning facilitates students to do simple project activities online. The results of interviews with students showed that learning during the pandemic students only did assignments in the form of answering questions contained on student worksheets and watching learning video shows through YouTube media. In addition, only three out of eight teachers interviewed used the learning model during online learning, and most students did not collect the assignments given by the teacher. Therefore, POEP learning will provide a meaningful learning experience for students even online. Based on the empirical facts that have been described, this study aimed to determine the effect of the PjBL, POE, and POEP models on metacognitive awareness and cognitive learning outcomes of students.

2. RESEARCH METHOD

The research applied quasi-experimental with pretest-posttest non-equivalent control group research design as shown in Table 1. Independent variables included the PjBL, POE, POEP, and conventional learning model implemented in four treatment classes. Participants were randomly selected. They consisted of 144 grade 10 high school students in Tarakan, Indonesia.

Table 1. Research design

Pretest	Treatment group	Class	Number of students	Post-test
O_1	PjBL	X MIPA 2	36	O_2
O_3	POE	X MIPA 3	36	O_4
O_5	POEP	X MIPA 4	36	O_6
O_7	Conventional	X MIPA 1	36	O_8

2.1. Instrument

The syllabus, lesson plan, student worksheet, metacognitive awareness questionnaire, and cognitive test were developed to collect the data. The metacognitive awareness questionnaire referred to the model of Schraw and Dennison [6] that consists of declarative knowledge, procedural knowledge, conditional knowledge, planning, information management strategies, monitoring, problem-solving strategies, and learning evaluation. The questionnaire consisted of 49 positive statements with a scale of 1 and 0 (1 is for "yes" and 0 for "no"). The cognitive test consisted of 10 multiple choice and five essay questions. The validity and reliability tests of the instruments were carried out using the Pearson Product Moment, and the reliability test was conducted using Cronbach's Alpha. The cognitive test instrument was confirmed valid with a value of 0.479 and reliable with a value of 0.373. The metacognition awareness questionnaire was confirmed valid with a value of 0.18 and reliable with a value of 1.16.

2.2. Procedures

The experiment was conducted for one semester, starting from August to December, 2020. It covered the scope of biology, biodiversity, classification of living things, bacteria, viruses, and protists. The learning activities were conducted online via Google Classroom during the COVID-19 pandemic. Google Classroom was applied in the research as it is considered more practical and easier to access [30], [31]. The teacher could equip students with pre-class online learning materials (modules, videos, and articles) and give quizzes or tasks via Google Classroom.

The implementation of learning in each class is as: i) PjBL as for the learning steps in the PjBL class, namely: determining the essential question, developing project planning, developing a project schedule, monitoring project progress, assessing the results, and evaluating experiences; ii) POE as for the learning steps in the POE class, namely: developing the predictions, making observations, and explaining the results of the observations; iii) POEP as for the learning steps in the POEP class, namely: predicting-designing project, observing-monitoring project, and explaining-evaluating project. The control class was taught using conventional learning, where learning lectures and doing assignments that are available in student worksheets.

2.3. Data analysis

Data were analyzed using analysis of covariance (ANCOVA) and least significant different (LSD) with the help of statistical product and service solutions (SPSS). Normality and homogeneity were tested first before analysis. Normality test was performed with the One Sample Kolmogorov-Smirnov Test, and homogeneity test was performed with Levene's test. ANCOVA and LSD were performed after the requirements were met to determine the POEP model's effect on metacognitive awareness and cognitive learning outcomes. The LSD test was performed to determine the significance level of the learning model.

3. RESULTS AND DISCUSSION

3.1. The results of normality and homogeneity tests of metacognitive awareness and cognitive learning outcome

The prerequisite before testing the hypothesis is to perform normality and homogeneity tests. The data are required to be normally distributed and homogeneous. The results of normality and homogeneity tests of metacognitive awareness and cognitive learning outcome are presented in Table 2.

Table 2 shows that the scores for students' metacognitive awareness and learning outcomes are normally distributed and homogeneous (level of significant>0.05). Therefore, hypothesis testing could be performed. Hypothesis testing was carried out using ANCOVA to determine the learning model's effect on students' metacognitive awareness and cognitive learning outcomes.

Table 2. The results of normality and homogeneity tests of students' metacognitive awareness and cognitive learning outcome

Treatment group	Normality		Homogeneity	
	N	Sig.	Score Levene's test	Sig.
Metacognitive awareness pretest	144	0.100	0.256	0.140
Metacognitive awareness post-test	144	0.084	0.271	0.050
Cognitive learning outcome pretest	144	0.150	0.280	0.005
Cognitive learning outcome post-test	144	0.100	0.083	0.002

3.2. The effect of PjBL, POE, POEP, and conventional learning on students' metacognitive awareness

The effect of PjBL, POE, POEP, and conventional learning on students' metacognitive awareness was obtained through the ANCOVA results with pretest scores as covariates. The effect of the learning model on students' metacognitive awareness is presented in Table 3. The table presents the differences in the learning model (F count=1.667 with p value=0.000 while the value of p<α (α=0.05)). Therefore, the proposed hypothesis was accepted. The learning model affects students' metacognitive awareness. Then, the LSD test was performed. The results are presented in Table 4.

Table 4 shows significant differences between conventional learning models, POE, PjBL, and POEP. It was reflected in the average posttest score. The POEP scored the highest (24.66), followed by PjBL (23.81), POE (23.52), and conventional learning (21.18). Based on these results, it was clear that the highest average score was in the POEP class. In detail, the average POEP, PjBL, POE, and conventional learning scores are presented in Figure 1.

Table 3. ANCOVA result (metacognitive awareness)

Source	Type III sum of squares	df	Mean square	F	Sig.
Corrected model	1033.117[a]	4	258.279	6.773	.000
Intercept	2842.919	1	2842.919	74.551	.000
Metacognitive awareness	812.693	1	812.693	21.311	.000
Class	190.702	3	63.567	1.667	.000
Error	4957.431	139	38.134		
Total	79304.000	144			
Corrected total	5990.548	143			

R squared=.172 (Adjusted R squared=.147)

Table 4. LSD test results (metacognitive awareness)

Class	Mean	LSD	Notation
Conventional	21.18	23.88	A
POE	23.52	26.23	Ab
PjBL	23.81	26.52	Ab
POEP	24.66	27.37	B

Figure 1 shows the students' metacognitive awareness scores. The maximum score for the aspect of declarative knowledge is 10. The graph shows that the highest score of 9 was achieved by the PjBL and POEP class, followed by the POE class that scored 8, and the lowest one was gained by the conventional class that scored 7. The maximum score for procedural knowledge was 4, and it was gained by the PjBL and POEP classes, while the POE and conventional classes scored 3. The maximum score for the aspect of conditional knowledge was 5, and it was gained by the POEP class, followed by PjBL class which scored 4, while the POE and conventional class both scored 3. The maximum score for the planning aspect was 5, and it was gained by the POEP class. PjBL class scored 4 while both POE and conventional class scored 3. The maximum score for the aspect of information management strategy was 8, and it was achieved by the POEP class while the PjBL class scored 7 followed by the POE class that scored 6, and the conventional class scored the lowest at 5. The maximum score for monitoring was 7, and it was gained by the POEP and PjBL classes while the POE class scored 5 followed by the conventional class that scored 4. The maximum score for the aspect of problem-solving strategies was 4, and it was gained by the PjBL class followed by the POEP, POE, and the conventional class that all scored 3. The maximum score for the aspect of evaluation was 6. PjBL class scored the highest at 5 followed by POEP, POE, and conventional class that scored 4, 3, and 2, respectively.

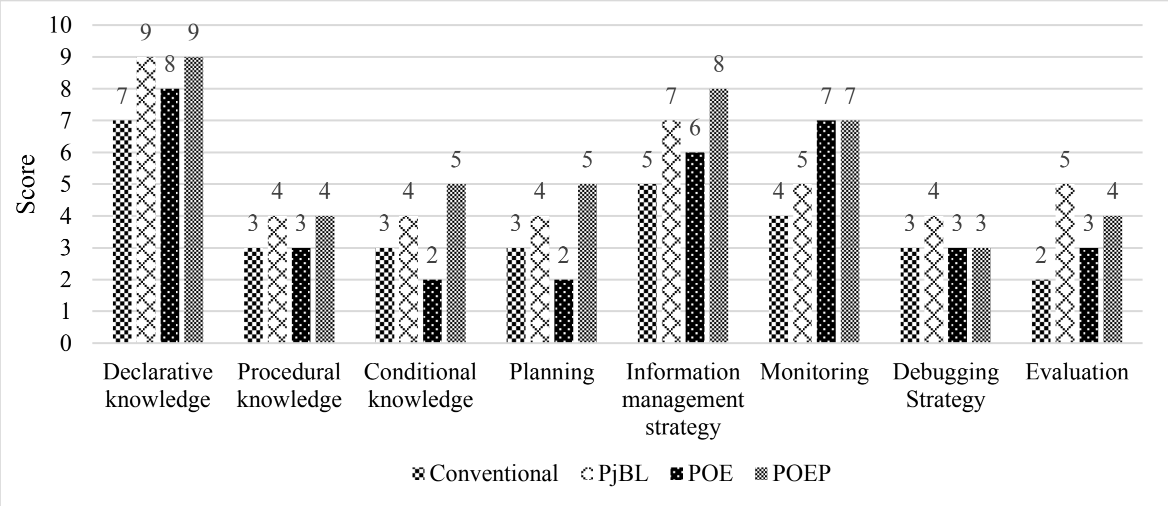


Figure 1. The average score of conventional, PjBL, POE, and POEP on metacognition awareness

The research discovered that learning models affected students' metacognitive awareness. It was also found that the POEP learning model provided the highest contribution to metacognitive awareness compared to PjBL and POE. POEP involved students in developing their knowledge about cognition and its regulating process. Students were asked to understand their strengths and weaknesses in learning, use strategies to learn, and use intellectual power to compensate for their weaknesses. This was manifested in the Predict-Design project activity in the first syntax. An example of students' prediction results in learning viruses is presented in Figure 2.

Figure 2 shows students' predictions about what would happen if the spread of COVID-19 was not contained. In arranging the predictions, students should have prior knowledge of the structure and reproduction of viruses in general. It would help them arrange relevant predictions and perform regulation in thinking. Bajar-Sales *et al*. [23] stated that the activity of predicting empowers metacognitive awareness. Besides, predicting activity improves the monitoring aspect of students' metacognitive awareness [32], [33]. After arranging the predictions, students formulated essential questions and designed project activities. When designing the project activities, students indirectly involved metacognitive awareness [34]. The observe-monitoring project in the second syntax trained students' metacognitive awareness through monitoring activity. Students who perform monitoring activities are those who develop their metacognitive awareness [35]. The explain-monitoring project in the third syntax trains students to reflect on the experience or learned lesson [36].

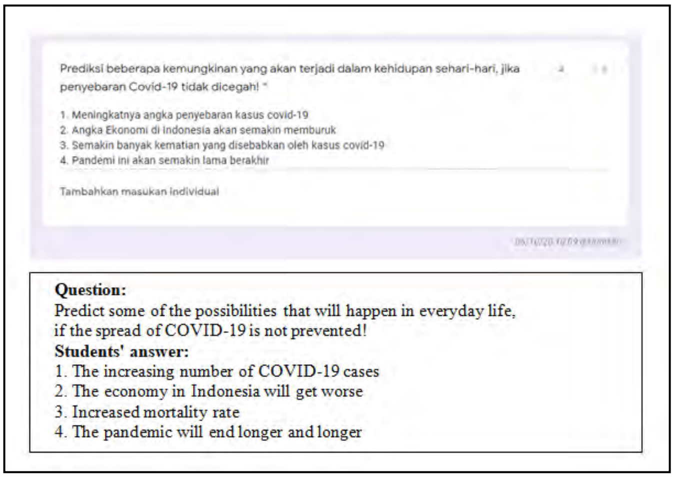


Figure 2. Students' prediction regarding the spread of COVID-19

3.3. The effect of PjBL, POE, POEP, and conventional learning on student's cognitive learning outcomes

The analysis of the learning model's effects on student cognitive learning outcomes is presented in Table 5. This table presents the differences in the learning model (F count=117.353 with a p value=0.000 while the value of p<α (α=0.05)). Therefore, the proposed hypothesis was accepted. The learning model affected students' learning outcomes. Then, the LSD test was performed and the results are presented in Table 6.

Table 5. ANCOVA result (cognitive learning outcome)

Source	Type III sum of squares	df	Mean square	F	Sig.
Corrected model	13541.641[a]	4	3385.410	28.848	.000
Intercept	27738.510	1	27738.510	236.367	.000
Cognitive learning outcome	1156.820	1	1156.820	9.858	.002
Class	12579.177	3	4193.059	35.730	.000
Error	15960.061	139	117.353		
Total	291761.000	144			
Corrected total	29501.000	143			

a.R squared=.459 (Adjusted R squared=.443)

Table 6. LSD test results (cognitive learning outcome)

Class	Mean	LSD	Notation
Conventional	34.50	39.05	a
POE	39.44	44.00	b
PjBL	39.51	44.07	bc
POEP	58.75	63.30	d

Table 4 shows significant differences between conventional learning models, POE, PjBL, and POEP. The average posttest score reflected it. The POEP scored the highest (34.50), followed by the PjBL (39.44), POE (39.51), and conventional learning (58.75). The average scores of POEP, PjBL, POE, and conventional learning in detail are presented in Figure 3.

Figure 3 shows the score of students' cognitive learning outcomes with a maximum score of 100. The aspects of remembering and understanding in all classes reached the maximum score. The conventional class gained the lowest score in the applying aspect with a score of 50. On the other hand, the PjBL, POE, dan POEP classes achieved the maximum score. The highest score in the aspect of analyzing was acquired by POEP class that gained 75. Meanwhile, the lowest score was obtained by the conventional class that scored 31. The highest score in the aspect of evaluating was achieved by POEP class that scored 63. The lowest score was gained by the conventional class that scored 25. The highest score in the aspect of creating was achieved by POEP class that gained 92. The conventional class scored the lowest at 42.

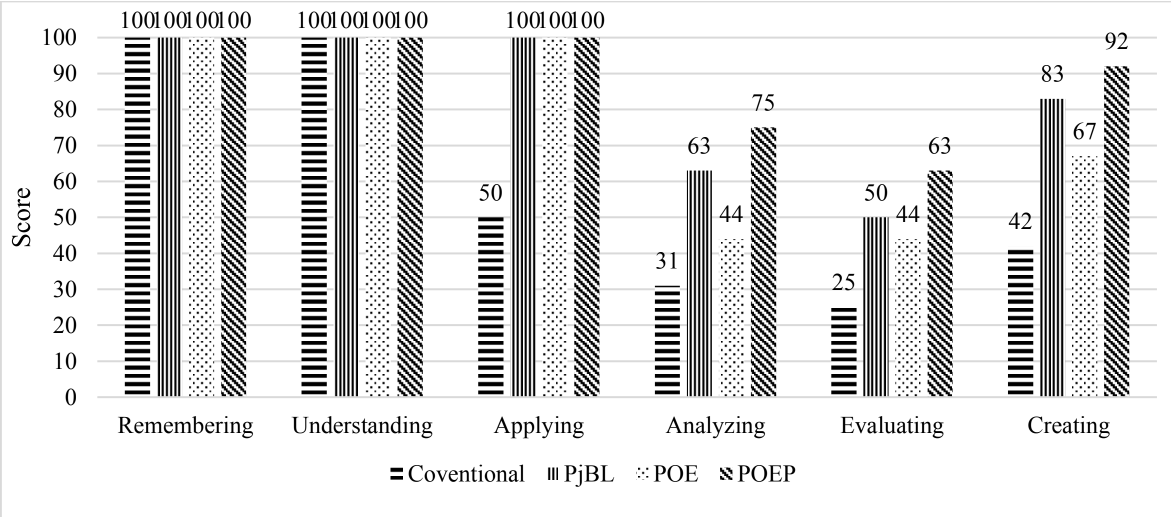


Figure 3. The average score of conventional, PjBL, POE, and POEP on cognitive learning outcomes

Research results showed that the learning model affected students' cognitive learning outcomes. However, it turned out that the POEP learning model provided the highest contribution to students' cognitive learning outcomes compared to PjBL and POE. POEP involved students in learning comprehensively through the predict-design project phase. Students were asked to formulate questions to help them arrange predictions. The collaborative problem formulation helps students master the concept thoroughly [14]. Students were asked to formulate relevant problems related to the scientific method in biology.

Figure 4 shows that students were able to formulate a problem that was relevant to the particular topic. Students could maximize their curiosity to explore. The problem formulation would help them arrange predictions and plan a project activity. Project activity involves higher-order thinking skills [37]. The observe-monitoring project in the next phase trains students to involve perception, experience, and conceptual knowledge. The observation could stimulate students to ask questions, connect previous experiences, collect information, and discover relationship patterns between events and objects [34]. Developing a habit of observation can improve students' understanding of science [35]. One of the student activities in the observe-monitoring project phase is presented in Figure 5.

Figure 5 shows students' observation result on mung bean germination in various light treatment. Glass A was placed in an open place, glass B was placed inside a room with lots of sunlight, glass C was placed in a room with limited sunlight, and glass D was placed inside a closed container. Students were surprised to find out that the mung bean placed inside a closed container had higher sprouts growth germination than the others as its sprout went through etiolation. Students then discussed the result and discovered the cause of etiolation during the germination process. Due to the lack of sunlight, etiolation resulted in auxin functioning actively and rapidly in cell division. However, the germination process with the absence of light caused the chlorophyll destruction that made the leaves smaller.

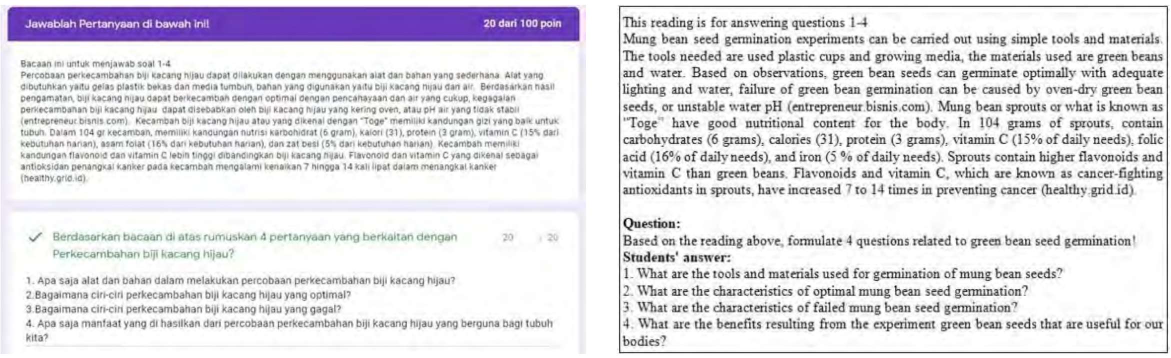


Figure 4. Problem formulations regarding the scientific method

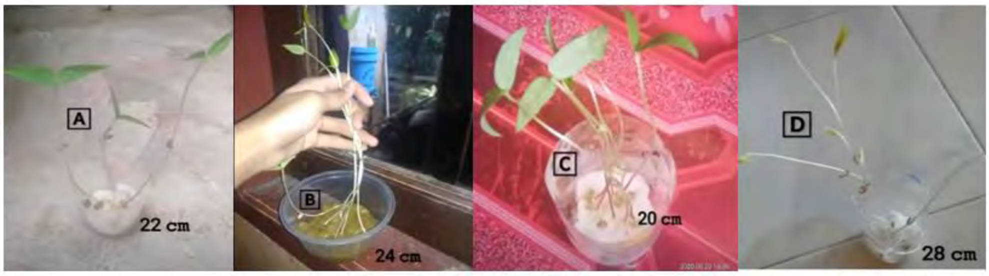
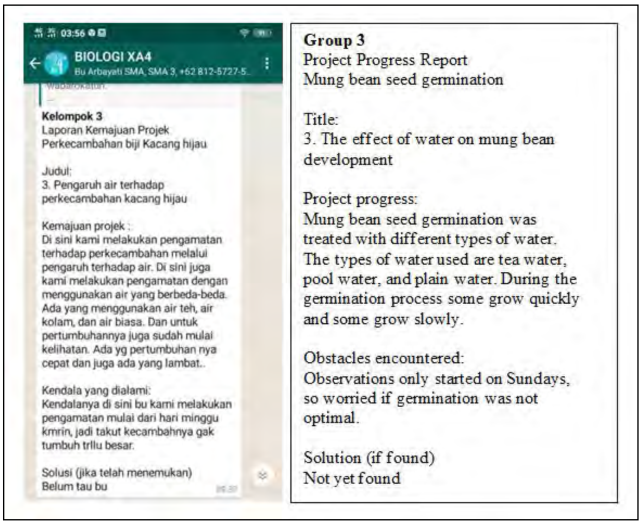


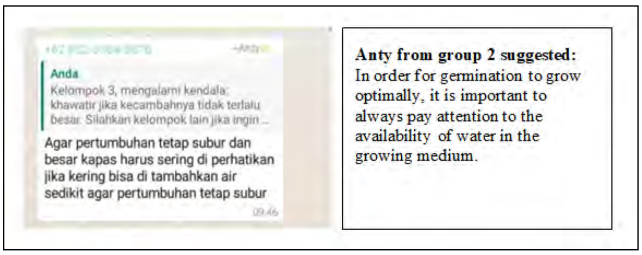
Figure 5. Student observation activities regarding mung bean germination

The observe-monitoring project phase stimulated students to think openly to understand the concept. Students understood the concepts, rules, and principles of scientific methods before demonstrating the germination experiment. The experiment was done in a group. Students then diagnosed the problems found and reported them as a form of project activity monitoring. The monitoring project was conducted according to the approved schedule by students and teacher via WhatsApp group (Figure 6).

Figure 6(a) shows the report on the student project activities progress and Figure 6(b) shows that students openly provided suggestions for other groups. In this phase, students detected the project's success and failure and then discovered the solutions. Furthermore, observation could be used to track how to comprehend students' understanding of a concept [36], [38]. Students could assess the project result through the explain-evaluate project phase. This ability is included in the cognitive domain of evaluating [39]. Moreover, students could provide the suggestion for other groups through presentation activities. The activity of explaining products could improve students' cognitive skills [39], [40]. Products presented by students are shown in Figure 7.



(a)



(b)

Figure 6. Monitoring project: (a) report on the student project activities progress and (b) suggestions from other groups

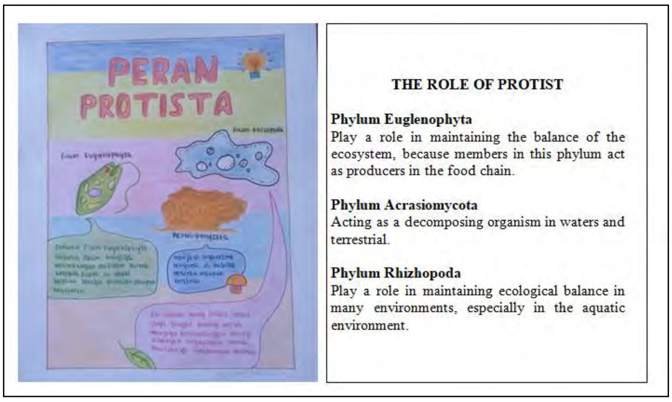


Figure 7. Students' product about protist

Figure 7 shows students explaining through posters the role of several protist phyla, including *Euglenophyta, Rhizophoda,* and *Acrasiomycota*. The phylum *Euglenophyta* plays a role in maintaining the balance of the ecosystem because members of this phylum act as producers in the food chain. *Rhizophods* which have artificial limbs such as *Entamoeba coli* play a role in the putrefaction of food waste in the human colon. *Acrasiomycota* is slime molds that function as decomposers. Based on this explanation, it can be concluded that students can analyze, evaluate knowledge, and make attractive posters. This is in line with the findings of Remmen and Froyland [39] who found that students who can provide detailed explanations have understood the concept comprehensively. In addition, the activity of presenting the results is considered to be able to improve students' critical thinking skills and cognitive learning outcomes, because students have a responsibility towards themselves to master the concept before being presented [18], [40].

4. CONCLUSION

The study confirmed that POEP was applicable to promote students' metacognitive awareness and cognitive learning outcomes. Metacognitive awareness and cognitive learning outcomes are components students should master. To discover more about the POEP potential, further research could be carried out at different education levels with different variables.

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REFERENCES

[1] S. Jaleel and P. Premachandran, "A Study on the Metacognitive Awareness of Secondary School Students," *Universal Journal of Educational Research*, vol. 4, no. 1, pp. 165–172, Jan. 2016, doi: 10.13189/ujer.2016.040121.
[2] N. Lara Nieto-Márquez, A. Baldominos, and M. Á. Pérez-Nieto, "Digital Teaching Materials and Their Relationship with the Metacognitive Skills of Students in Primary Education," *Education Sciences*, vol. 10, no. 4, p. 113, Apr. 2020, doi: 10.3390/educsci10040113.
[3] A. V. Cyril and M. A. Raj, "Emotional Maturity and Metacognition of High School Teachers," *i-Manager's Journal on Educational Psychology*, vol. 12, no. 2, p. 36, 2018.
[4] C. H. Padmanabha, "Metacognition: Conceptual Framework," *i-manager's Journal on Educational Psychology*, vol. 14, no. 1, p. 1, 2020, doi: 10.26634/jpsy.14.1.16710.
[5] E. Fox and M. Riconscente, "Metacognition and Self-Regulation in James, Piaget, and Vygotsky," *Educational Psychology Review*, vol. 20, no. 4, pp. 373–389, Dec. 2008, doi: 10.1007/s10648-008-9079-2.
[6] G. Schraw and R. S. Dennison, "Assessing metacognitive awareness," *Contemporary Educational Psychology*, vol. 19, no. 4, pp. 460–475, Oct. 1994, doi: 10.1006/ceps.1994.1033.
[7] C. Thenmozhi, "Models of Metacognition," *Shanlax International Journal of Education*, vol. 7, no. 2, pp. 1–4, Mar. 2019, doi: 10.34293/education.v7i2.303.
[8] T. García, C. Rodríguez, P. González-Castro, J. A. González-Pienda, and M. Torrance, "Elementary students' metacognitive processes and post-performance calibration on mathematical problem-solving tasks," *Metacognition and Learning*, vol. 11, no. 2, pp. 139–170, Aug. 2016, doi: 10.1007/s11409-015-9139-1.
[9] D. Purnomo, T. Nusantara, S. Subanji, and S. Rahardjo, "The Characteristic of the Process of Students' Metacognition in Solving Calculus Problems," *International Education Studies*, vol. 10, no. 5, p. 13, Apr. 2017, doi: 10.5539/ies.v10n5p13.

[10] F. Radmehr and M. Drake, “Exploring students’ metacognitive knowledge: The case of integral calculus,” *Education Sciences*, vol. 10, no. 3, p. 55, Mar. 2020, doi: 10.3390/educsci10030055.

[11] Idawati, P. Setyosari, D. Kuswandi, and S. Ulfa, “Investigating the effects of problem-solving method and cognitive flexibility on improving university students’ metacognitive skills,” *Journal for the Education of Gifted Young Scientists*, vol. 8, no. 2, pp. 657–680, Jun. 2020, doi: 10.17478/jegys.652212.

[12] S. C. Choy, J. S. C. Yim, and P. L. Tan, “Mediating effects of quality learning on metacognitive knowledge, metacognitive experience and outcomes,” *Issues in Educational Research*, vol. 29, no. 1, pp. 1–18, 2019.

[13] B. Kramarski, Z. R. Mevarech, and M. Arami, “The effects of metacognitive instruction on solving mathematical authentic tasks,” *Educational Studies in Mathematics*, vol. 49, no. 2, pp. 225–250, 2002, doi: 10.1023/A:1016282811724.

[14] M. G. Rhodes, “Metacognition,” *Teaching of Psychology*, vol. 46, no. 2, pp. 168–175, Apr. 2019, doi: 10.1177/0098628319834381.

[15] S. L. Zorluoğlu and Ç. Güven, “Analysis of 5th Grade Science Learning Outcomes and Exam Questions According to Revised Bloom Taxonomy,” *Journal of Educational Issues*, vol. 6, no. 1, p. 58, Mar. 2020, doi: 10.5296/jei.v6i1.16197.

[16] V. Prachagool and P. Nuangchalerm, “Investigating understanding the nature of science,” *International Journal of Evaluation and Research in Education (IJERE)*, vol. 8, no. 4, p. 719, Dec. 2019, doi: 10.11591/ijere.v8i4.20282.

[17] D. Adom, J. Adu-Mensah, and D. A. Dake, “Test, measurement, and evaluation: Understanding and use of the concepts in education,” *International Journal of Evaluation and Research in Education (IJERE)*, vol. 9, no. 1, p. 109, Mar. 2020, doi: 10.11591/ijere.v9i1.20457.

[18] N. Hasnunidah, H. Susilo, M. Irawati, and H. Suwono, “The contribution of argumentation and critical thinking skills on students’ concept understanding in different learning models,” *Journal of University Teaching and Learning Practice*, vol. 17, no. 1, pp. 80–91, Jan. 2020, doi: 10.53761/1.17.1.6.

[19] S. Ilma, M. H. I. Al-Muhdhar, F. Rohman, and M. Saptasari, “The correlation between science process skills and biology cognitive learning outcome of senior high school students,” *JPBI (Jurnal Pendidikan Biologi Indonesia)*, vol. 6, no. 1, Mar. 2020, doi: 10.22219/jpbi.v6i1.10794.

[20] N. Foldnes, “The flipped classroom and cooperative learning: Evidence from a randomised experiment,” *Active Learning in Higher Education*, vol. 17, no. 1, pp. 39–49, Mar. 2016, doi: 10.1177/1469787415616726.

[21] H. A. McQueen and C. McMillan, “Quectures: Personalised constructive learning in lectures,” *Active Learning in Higher Education*, vol. 21, no. 3, pp. 217–231, Nov. 2020, doi: 10.1177/1469787418760325.

[22] T. Nalkiran and S. Karamustafaoğlu, “Prediction-Observation-Explanation (POE) Method and Its Efficiency in Teaching ‘Work, Energy, Power’ Concepts,” *International Journal of Assessment Tools in Education*, vol. 7, no. 3, pp. 497–521, 2020, doi: 10.21449/IJATE.727399.

[23] P. A. B. Sales, R. A. Avilla, and V. M. I. Camacho, “Predict-Explain-Observe-Explain (PEOE) Approach : Tool in Relating Metacognition To Achievement in Chemistry,” *Electronis Journal Of Science Education*, vol. 151, no. 1, pp. 10–17, 2015.

[24] D. Susanti, C. Anwar, F. G. Putra, Netriwati, K. Afandi, and S. Widyawati, “The Influence of Learning Model Discovery Learning Type POE and Learning Activities on Metacognitive Ability (in Indonesian),” *INOMATIKA*, vol. 2, no. 2, pp. 93–105, Jun. 2020, doi: 10.35438/inomatika.v2i2.199.

[25] D. Furqani, S. Feranie, and N. Winarno, “The Effect of Predict-Observe-Explain (POE) Strategy on Students’ Conceptual Mastery and Critical Thinking in Learning Vibration and Wave,” *Journal of Science Learning*, vol. 2, no. 1, p. 1, Dec. 2018, doi: 10.17509/jsl.v2i1.12879.

[26] E. Viro, D. Lehtonen, J. Joutsenlahti, and V. Tahvanainen, “Teachers’ perspectives on project-based learning in mathematics and science,” *European Journal of Science and Mathematics Education*, vol. 8, no. 1, pp. 12–31, Jan. 2020, doi: 10.30935/scimath/9544.

[27] H. Habibi, M. Mundilarto, J. Jumadi, S. Gummah, S. Ahzan, and D. S. B. Prasetya, “Project brief effects on creative thinking skills among low-ability pre-service physics teachers,” *International Journal of Evaluation and Research in Education (IJERE)*, vol. 9, no. 2, p. 415, Jun. 2020, doi: 10.11591/ijere.v9i2.20531.

[28] P. N. Eckardt, M. Craig, and L. Kraemer, “The Impact of Project-Based Learning on Student Content Knowledge in an Undergraduate, Teacher Preparation, Foundations of Education Course,” *Journal for Leadership and Instruction*, vol. 19, no. 1, pp. 38–42, 2020.

[29] S. Bakkaloglu, “Analysis of Metacognitive Awareness of Primary and Secondary School Students in Terms of Some Variables,” *Journal of Education and Learning*, vol. 9, no. 1, p. 156, Jan. 2020, doi: 10.5539/jel.v9n1p156.

[30] M. Olesen, “Cooperative Collaboration in the Hybrid Space of Google Docs Based Group Work,” *Education Sciences*, vol. 10, no. 10, p. 269, Sep. 2020, doi: 10.3390/educsci10100269.

[31] K. R. Heggart and J. Yoo, “Getting the most from google classroom: A pedagogical framework for tertiary educators,” *Australian Journal of Teacher Education*, vol. 43, no. 3, pp. 140–153, Mar. 2018, doi: 10.14221/ajte.2018v43n3.9.

[32] E. E. Howe, “Does Metacognitive Reflection Benefit Art Students?” *International Dialogues on Education Journal*, vol. 6, no. 2, pp. 139–163, Nov. 2019, doi: 10.53308/ide.v6i2.65.

[33] T. M. Miller and L. Geraci, “Training metacognition in the classroom: The influence of incentives and feedback on exam predictions,” *Metacognition and Learning*, vol. 6, no. 3, pp. 303–314, Dec. 2011, doi: 10.1007/s11409-011-9083-7.

[34] A. Oguz-Unver and K. Yurumezoglu, “A Teaching Strategy for Developing the Power of Observation in Science Education,” *Ondokuz Mayis University Journal of Education*, no. 28, pp. 105–119, 2009.

[35] L. Topinka and D. T. Sands, “Sketching as a science tool,” *Connect Magazine*, vol. 19, pp. 4–7, 2005.

[36] C. H. Hill and P. Grossman, “Learning from Teacher Observations: Challenges and Opportunities Posed by New Teacher Evaluation Systems,” *Harvard Educational Review*, 2013.

[37] J. W. Mahoney and B. Harris-Reeves, “The effects of collaborative testing on higher order thinking: Do the bright get brighter?” *Active Learning in Higher Education*, vol. 20, no. 1, pp. 25–37, Mar. 2019, doi: 10.1177/1469787417723243.

[38] J. N. Mikeska, S. Holtzman, D. F. McCaffrey, S. Liu, and T. Shattuck, “Using classroom observations to evaluate science teaching: Implications of lesson sampling for measuring science teaching effectiveness across lesson types,” *Science Education*, vol. 103, no. 1, pp. 123–144, Jan. 2019, doi: 10.1002/sce.21482.

[39] K. B. Remmen and M. Frøyland, “Students’ use of observation in geology: towards ‘scientific observation’ in rock classification,” *International Journal of Science Education*, vol. 42, no. 1, pp. 113–132, Jan. 2020, doi: 10.1080/09500693.2019.1704914.

[40] N. Simper, R. Reeve, and J. R. Kirby, “Effects of Concept Mapping on Creativity in Photo Stories,” *Creativity Research Journal*, vol. 28, no. 1, pp. 46–51, Jan. 2016, doi: 10.1080/10400419.2016.1125263.

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