



# Investigating the relationship between metacognitive and critical thinking skills in preservice teachers: Insights from predict-observe-explain and direct instruction learning models

Shefa Dwijayanti Ramadani <sup>(1)\*</sup>, Bea Hana Siswati <sup>(2)</sup>,  
Serafica Btari Christiyani Kusumaningrum <sup>(1)</sup>

<sup>(1)</sup> Department of Biology Education, Faculty of Teacher Training and Education, Universitas Tidar, Magelang, Central Java, Indonesia

<sup>(2)</sup> Department of Biology Education, Faculty of Education, Universitas Jember, Jember, East Java, Indonesia

\* Corresponding Author Email: [shefa@untidar.ac.id](mailto:shefa@untidar.ac.id)

| Article Information                                                                                                                                                                                                                                                                                                                                | Abstract                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p><b>Keyword:</b><br/>Critical thinking; Predict-observe-explain; Metacognitive; Active learning</p> <p><b>Kata Kunci:</b><br/>Berpikir kritis; Predict-observe-explain; Metakognisi; Pembelajaran aktif</p> <hr/> <p><b>History:</b><br/>Received : 07/08/2025<br/>Revised : 13/09/2025<br/>Accepted : 22/09/2025<br/>Published : 25/09/2025</p> | <p>Metacognitive and critical thinking skills are widely recognized as essential components of higher-order thinking and play a key role in supporting academic success and lifelong learning. However, research exploring the interplay between these skills has often been conducted partially. This study aims to: (1) investigate the relationship between metacognitive and critical thinking skills within the active learning strategy Predict-Observe-Explain (POE) and direct instruction learning models (DI); and (2) analyze differences in the metacognitive and critical thinking skills scores of students taught with POE and DI learning strategies. A quantitative research method with a correlational design was used in this study. Data were collected from essay tests integrated with metacognitive and critical thinking skills rubrics at the end of the implementation of learning in classes that apply POE and DI. The data obtained were then analyzed using regression and t-tests. The results indicate a positive, strong, and significant relationship between metacognitive skills and critical thinking in both learning models. Additionally, the average critical thinking scores were significantly higher in the POE model than in DI, while there was no significant difference in students' metacognitive skills. These findings suggest that constructivist-based POE learning can effectively promote critical thinking. Consequently, educators are encouraged to incorporate POE into instructional practices to support the development of metacognitive and thinking skills among students.</p> <p><i><b>Abstrak.</b> Keterampilan metakognitif dan berpikir kritis telah dikenal luas sebagai komponen penting dari kemampuan berpikir tingkat tinggi, serta memiliki peranan kunci untuk mendukung keberhasilan akademis maupun kemampuan belajar sepanjang hayat. Akan tetapi, penelitian yang mengeksplorasi interaksi antara keterampilan ini sering kali dilakukan secara parsial. Penelitian bertujuan untuk mengkaji hubungan antara keterampilan metakognitif dan berpikir kritis pada strategi pembelajaran aktif Predict-Observe-Explain (POE) dan pembelajaran langsung (DI), serta membandingkan efektivitas kedua strategi pembelajaran dalam menumbuhkan keterampilan tersebut. Metode penelitian eksperimental dengan desain korelasional digunakan dalam penelitian ini. Data dikumpulkan dari tes esai yang diintegrasikan dengan rubrik keterampilan metakognitif dan berpikir kritis pada akhir pelaksanaan pembelajaran di kelas yang menerapkan POE dan pembelajaran langsung. Data yang diperoleh kemudian dianalisis menggunakan regresi dan uji-t. Hasil penelitian menunjukkan bahwa terdapat hubungan yang positif, kuat, dan signifikan antara keterampilan metakognitif dan berpikir kritis pada implementasi kedua model pembelajaran. Adapun rerata skor keterampilan berpikir kritis secara signifikan lebih tinggi pada pembelajaran yang menerapkan POE dibandingkan model pembelajaran langsung, sementara keterampilan metakognitif mahasiswa tidak berbeda signifikan. Temuan ini menunjukkan bahwa strategi POE yang berbasis konstruktivisme dapat secara efektif meningkatkan pemikiran kritis. Oleh karenanya, pendidik diharapkan untuk mengintegrasikan POE ke dalam praktik pengajaran untuk mendukung pengembangan keterampilan metakognitif dan berpikir kritis siswa.</i></p> |

## A. Introduction

The priority of educational institutions today is to create a productive, creative, innovative, and effective generation through the integration of attitudes, abilities, and knowledge with life skills as a provision to face the challenges of the 21st century (Andrini, 2016; Kabeel & Eisa, 2016; Taghva et al., 2014). Researchers and educators have made various efforts to meet these challenges, one of which is through the study of metacognitive skills and critical thinking as an important component of higher thinking skills and is widely recognized as a valuable asset for academic success and lifelong learning abilities (Aleven & Koedinger, 2002; Maor et al., 2023).

Metacognition is simply defined as “thinking about thinking” (Flavell, 1979). This concept involves reflective skills and the ability to regulate mental processes independently, thus allowing individuals to reflect, understand, and regulate their thought processes to achieve desired goals (Jin & Ji, 2020; Drigas et al., 2023). Well-developed metacognitive skills allow a person to control his or her learning process, seek answers to a lack of understanding, question the meaning of knowledge, and explore his or her self-understanding. Therefore, metacognitive skills are a key element that students need to possess to improve their thinking capacity (Kozikoğlu, 2019).

Another important skill that needs to be mastered as a 21st century skill is critical thinking. Critical thinking plays a central role in the process of logical thinking, making informed decisions, and effective problem-solving (Butler et al., 2012). Currently, critical thinking is even realized as an educational output that is highly valued at all levels of education, especially in higher and professional education (Zanden et al., 2020) because it is considered an effective contributor in the global world of work (Liu et al., 2014). This has implications for the need to design educational strategies to develop students' critical thinking skills. Through these skills, students are expected to be able to observe every problem comprehensively, so that they are better prepared to face global competition.

Previous research has provided evidence regarding the importance of metacognition and critical thinking skills in Higher Education (Räsänen et al., 2021; Tuononen et al., 2023). However, research investigating the relationship between these two domains and their potential influence on each other is still limited (Mall-Amiri & Ahmadi, 2014; Arslan, 2018). Research conducted by Semerci & Elaldı (2014) shows a significant relationship between all subdimensions of metacognitive beliefs and students' critical thinking values. Several studies have also stated a positive correlation between metacognitive and critical thinking skills (Cakici, 2018; Gurcay & Ferah, 2018). These results align with other studies that found a positive correlation between metacognitive and critical skills in students

at Sakarya University, Turkey (Arslan, 2018). Nevertheless, no research has specifically investigated the correlation between metacognitive and critical thinking skills and their comparison in implementing different learning strategies.

Vezzosi (2004) revealed that the fundamental aspect of critical thinking is metacognitive activity that reflects the extent of students' thinking, so they can evaluate the results of thinking and learning from experiences. Metacognitive skills are also related to developing critical thinking and are essential in improving students' cognitive abilities (Warni et al., 2018). Unfortunately, students' thinking and metacognitive skills revealed in high school (Corebima, 2016) and college students are still in the low category (Bahri & Corebima, 2015).

Previous studies showed that students who had difficulty reflecting on their learning process indicated that they lacked metacognitive skills to regulate their learning process (Räsänen et al., 2021). For biology education students, skill mastery related to critical thinking skills is also not as expected. This is shown by the average score of the critical thinking skills essay test which is in the underdeveloped category (Amin et al., 2017). Most biology students are also not able to monitor their thought processes, so the test results are not satisfactory (Saputri, 2017).

Teaching and learning should empower students' metacognitive skills by applying appropriate learning strategies. Metacognitive skills training is needed to increase students' awareness of learning, plan their learning, control the learning process, encourage critical thinking to evaluate one's effectiveness as a student, and to reflect on one's learning, as well as to evaluate one's strengths and abilities, as well as one's weaknesses (Bahri & Corebima, 2015). Ideally, empowering metacognitive skills and critical thinking is not a standalone activity. Instead, this skill can be improved by implementing various learning strategies.

The problem-solving approach carried out in this study is to examine the correlation between metacognitive and critical thinking skills in the application of constructivist-based active learning and compare them with the application of direct learning, so that the exact correlation and regression equation will be revealed, especially related to the effectiveness of the regression line, as well as the contribution of metacognitive skill development to thinking ability. Furthermore, it is also necessary to identify more effective learning strategies for developing these two higher-order thinking skills. This supports the findings of Tuononen et al. (2023) that the two dimensions of metacognitive awareness, namely knowledge and cognitive regulation, are significantly related to deep learning approaches and organized learning and negatively correlated with non-reflective

learning approaches such as those that focus on memorization and repetition of concepts.

Predict-Observe-Explain (POE) is one of the constructivist-based learning models that is suitable to be applied in Biology lectures that require laboratory activities or in a classroom environment that allows students to associate scientific information with natural events encountered in daily life. This strategy is characterized by estimating, carrying out observations, comparing and explaining predictions with observations, revealing initial knowledge, and allowing learners to find alternative solutions to complex problems (Erdem Özcan & Uyanık, 2022). Thus, more specifically, the formulation of the problem of this study, namely:

- 1) How do metacognitive and critical thinking skills correlate in implementing Predict-Observe-Explain (POE) and Direct Learning (DI) learning strategies?
- 2) Is there any significant difference in the metacognitive and critical thinking skills score of students taught with POE and DI learning strategy?

## B. Material and method

To answer the research questions, two approaches were employed. A correlational method was used to examine the relationship between students' metacognitive and critical thinking skills, while a quasi-experimental posttest-only design was applied to compare students taught with POE and DI strategies. This design, which Creswell (2019) identifies as a variation of quasi-experimental methods, was chosen because it allows for a practical comparison between existing classroom groups without disrupting the natural learning setting. However, since the design does not involve random assignment and relies solely on posttest scores, it has limitations in establishing initial group equivalence and in controlling potential confounding variables, which should be considered when interpreting the findings.

The population of the study is all Biology education students of FKIP Tidar University in the 2024/2025 academic year. The sample used was 67 Biology education students who programmed the Plant Physiology course in the 2024/2025 academic year. Of these, as many as 30 students in one of the classes received learning with the POE strategy, while 32 other students in different classes received the DI strategy. Overall, this research was carried out in three main stages, namely preparation, implementation, and completion (Figure 1).

In the preparation stage, curriculum mapping was conducted, followed by an analysis of learning outcomes and essential materials. This was continued with the development of instructional tools, including lesson plans, teaching materials, student worksheets, and supporting learning media. Additionally, research

instruments were prepared, consisting of metacognitive skill assessment rubrics and critical thinking ability assessment rubrics.

During the implementation stage, the learning process was carried out in accordance with the course syllabus (RPS), applying both the POE strategy and DI strategy. The POE strategy was implemented through three phases including making predictions, conducting observations, and providing explanations. In this process, students were first asked to predict the outcome of a demonstration, event, or experiment. They then made observations to gather data and subsequently explained their findings based on the comparison between their predictions and the observations. In contrast, the DI strategy was implemented through lectures and practicum sessions, aligned with the intended learning outcomes. In the fifth week of instruction, tests were administered to measure students' metacognitive and critical thinking skills in each group.

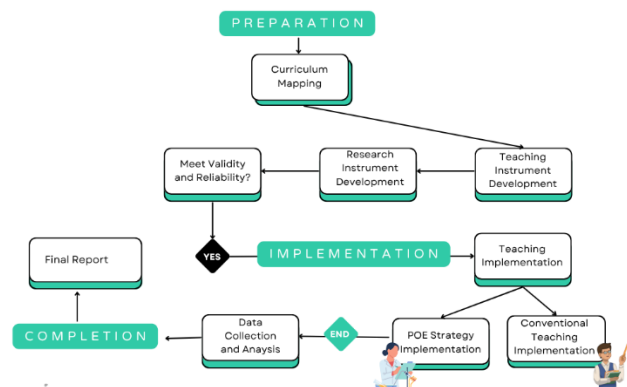


Figure 1 Research process

The data collected in this study are metacognitive and critical thinking skills. The researcher used the essay test instrument at the beginning and end of the research, then evaluated using the metacognitive skill assessment rubric and the critical thinking skills rubric. The rubric of metacognitive skills refers to the results of development Corebima (2009). The rubric consists of 7 scales (0-7) and is used as a reference to evaluate the results of students' answers. The score obtained is then calculated using the following Formula 1.

$$x = \frac{3y2 - y1}{2} \dots\dots\dots \text{Formula 1}$$

Description:

- x = metacognitive skill score
- y1 = concept comprehension score
- y2 = scores obtained from the metacognitive skills integrated concept understanding test

Meanwhile, critical thinking skills were measured using the critical thinking rubric first developed by Finken and Ennis and later modified by

Zubaidah et al. (2015) to a scale of 5 (0-5). Components of the instrument include focus, reasoning (reason or idea), organization (way of thinking), conventions (grammar) and integration of students' answers. The scores from the metacognitive skills and critical thinking data were then converted in the score range of 0-100 to facilitate the data analysis process.

Data analysis related to the correlation of metacognitive skills and critical thinking skills used regression analysis with a significance level of 0.05; while to compare the effectiveness of the two learning models, differential test analysis was used using a non-paired t-test. Before analysis, the data is first tested using the Kolmogorov-Smirnov One-Sample test to find out the normality of distributed data and the Levene test to determine the homogeneity of the data. The results showed that metacognitive skill data were distributed normally (0.061 and 0.159) and homogeneous (0.848). The data on students' critical thinking skills also showed a normal (0.189 and 0.190) and homogeneous (0.064) distribution.

### C. Results and discussion

*Correlation between metacognitive and critical thinking skills in the implementation of POE and DI strategies*

The results of the regression analysis regarding the correlation of metacognitive skills and critical thinking skills in Predict, Observe, and Explain (POE) learning strategies can be seen in Table 1 and Table 2.

The results of data analysis Table 1 Table 2 show a value of  $R = 0.839$ , a value of  $F = 66.385$  with a significance level of 0.00. This indicates a positive, strong, and significant relationship between metacognitive skills and students' critical thinking skills in the application of POE. The analysis also

revealed that the value of  $R^2 = 0.7033$  means that metacognitive skills contributed 70.33% to critical thinking ability in POE based learning, while the remaining 29.67% contributed to other factors besides metacognitive skills. This is in line with the opinion of Kuhn and Dean (2004) that critical thinking requires awareness of one's own thoughts and reflection on the thinking of self and others as an object of cognition, which is called metacognition. However, it is possible that additional factors may contribute to the development of critical thinking, such as the use of active learning models along with students' psychological and social characteristics. Zarzycka and Gesek (2022) highlighted several determinants of critical thinking advancement, including prevalent teaching methods which promote development of critical thinking, such as active learning strategies, concept mapping, simulations, problem-based learning, case studies, and evidence-based instructional methods. Furthermore, cultural and individual factors like empathy, emotional intelligence, and caring attitudes appear to have a significant association with critical thinking.

To elaborate further on these results, Table 3 presents the regression coefficient analysis of metacognitive skills and critical thinking skills within the POE strategy, while Figure 2 illustrates the corresponding regression equation. Table 3 shows a constant value of 44.900 for critical thinking and 0.562 for metacognitive skills. Thus, the regression equation obtained was  $y = 44.9 + 0.562x$ . This equation indicates that students' critical thinking skills increase by 0.562 points for every one-point increase in their metacognitive skills. In other words, an enhancement in students' metacognition is accompanied by an improvement in their critical thinking abilities.

**Table 1 Summary of regression analysis related to the relationship between metacognitive skills and critical thinking in the POE learning strategy**

| Learning strategy | R                 | R square | Adjusted R square | Std. error of the estimate |
|-------------------|-------------------|----------|-------------------|----------------------------|
| POE               | .839 <sup>a</sup> | .703     | .693              | 6.82731                    |

**Table 2 ANOVA test results of metacognitive skills and critical thinking skills on the implementation of POE strategy**

| Model      | Sum of squares | df | Mean square | F      | Sig.               |
|------------|----------------|----|-------------|--------|--------------------|
| Regression | 3094.326       | 1  | 3094.326    | 66.385 | 0.000 <sup>b</sup> |
| Residual   | 1305.140       | 28 | 46.612      |        |                    |
| Total      | 4399.467       | 29 |             |        |                    |

**Table 3 Analysis of the regression coefficient of metacognitive skills and critical thinking skills in the implementation of POE strategy**

| Model         | Unstandardized coefficients |            | Standardized coefficients |  | t      | Sig. |
|---------------|-----------------------------|------------|---------------------------|--|--------|------|
|               | B                           | Std. error | Beta                      |  |        |      |
| 1 Constan     | 44.900                      | 3.082      |                           |  | 14.568 | .000 |
| Metacognitive | .562                        | .069       | .839                      |  | 8.148  | .000 |

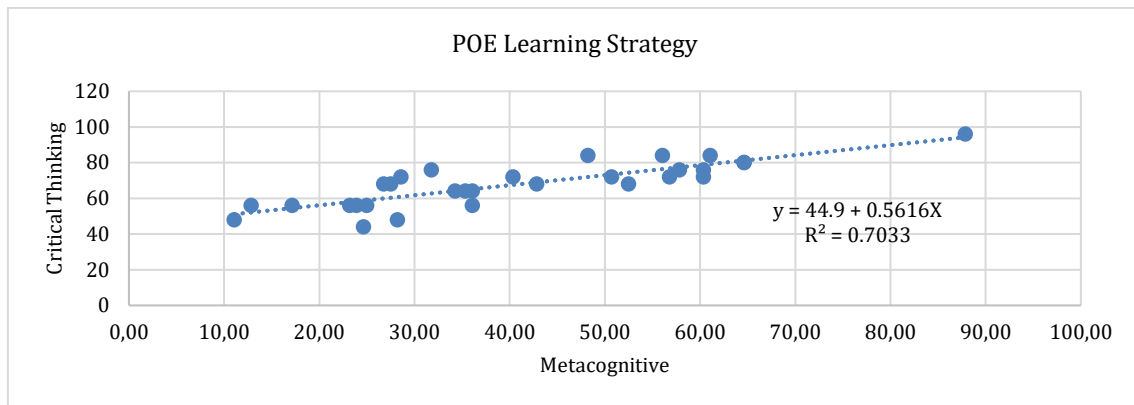


Figure 2 Graph of regression equations of metacognitive skills and critical thinking skills in the Implementation of POE

**Table 4 Summary of regression analysis related to the relationship between metacognitive skills and critical thinking in the DI learning strategy**

| Learning strategy | R                 | R square | Adjusted R square | Std. error of the estimate |
|-------------------|-------------------|----------|-------------------|----------------------------|
| DI                | .699 <sup>a</sup> | .488     | .471              | 6.22478                    |

**Table 5 ANOVA test results of metacognitive skills and critical thinking skills in the implementation of DI strategies**

|   | Model      | Sum of squares | df | Mean square | F      | Sig.              |
|---|------------|----------------|----|-------------|--------|-------------------|
| 1 | Regression | 1109.063       | 1  | 1109.063    | 28.623 | .000 <sup>b</sup> |
|   | Residual   | 1162.437       | 30 | 38.748      |        |                   |
|   | Total      | 2271.500       | 31 |             |        |                   |

**Table 6 Analysis of the regression coefficient of metacognitive skills and critical thinking skills in the implementation of DI strategies**

| Model         | Unstandardized coefficients |            | Standardized coefficients |  | t     | Sig. |
|---------------|-----------------------------|------------|---------------------------|--|-------|------|
|               | B                           | Std. error | Beta                      |  |       |      |
| 1 (Constant)  | 38.220                      | 3.835      |                           |  | 9.966 | .000 |
| Metacognitive | .490                        | .092       | .699                      |  | 5.350 | .000 |

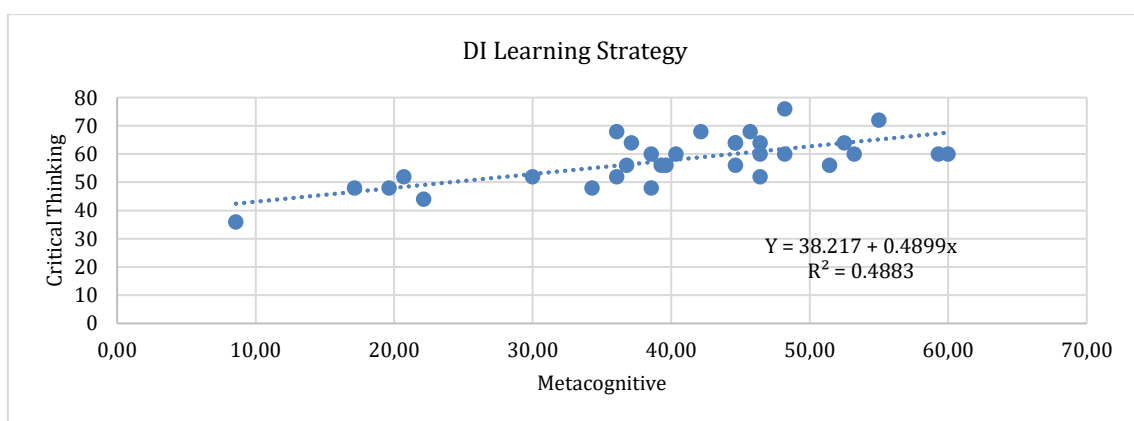


Figure 3 Graph of regression equations of metacognitive skills and critical thinking skills in the Implementation of Direct Learning

Furthermore, the results of the regression analysis of the correlation of metacognitive skills and critical thinking skills in Direct Learning (DI) strategies can be seen in Table 4 and Table 5. The results of data analysis in Tables 4 and 5 showed a value of  $R = 0.699$ , and a value of  $F = 28.623$  with a significance value of correlation between

metacognitive skills and critical thinking skills of 0.00. This means a positive, strong, and significant correlation exists between metacognitive skills and critical thinking skills in implementing DI learning. The analysis results also showed a value of  $R^2 = 0.4883$ , meaning that metacognitive skills contributed 48.83% to critical thinking skills, while the remaining

51.17% came from factors other than metacognitive skills. Furthermore, to find the coefficients and regression equations, the analysis was carried out and presented in Table 6.

Table 6 shows a constant value of 38.22 for critical thinking and 0.490 for metacognitive skills. Thus, the regression equation obtained was  $y = 38.22 + 0.490x$ . This equation shows that critical thinking skills improve by 0.490 for each increase in metacognitive scores. It can also be interpreted that the improvement of students' metacognition is followed by the improvement of students' critical thinking skills. A graph of the related regression equations is presented in Figure 3.

Based on the results of the analysis obtained, a significant correlation between metacognition and critical thinking in both learning strategies shows that metacognition plays an important role in the development of critical thinking skills. These results confirm the findings of previous research showing that metacognitive skills play an important role in developing students' critical thinking skills. For example, Akcaoglu et al. (2023); Arslan et al. (2013) and Jin & Ji (2020) reported that there is a positive, strong, and significant relationship between metacognitive skills, independent learning abilities, and critical thinking in college students. Magno (2010) obtained similar results when testing a model in which metacognition is used to predict critical thinking. His findings suggest that the ability to monitor one's knowledge and thought processes supports the development of critical thinking skills. Thus, students who have good metacognitive abilities are better able to monitor and reflect on their own thought processes, so they can contribute to the improvement of critical thinking skills.

The contribution of metacognitive to critical thinking skills within the POE strategy is supported by the strengths of this instructional approach. POE encourages students to actively engage in predicting, observing, and explaining scientific phenomena, which in turn fosters the activation and development of their metacognitive processes. This strategy also reinforces students' involvement in inquiry-based learning, as it facilitates meaningful knowledge construction through conceptual problem-solving and hands on scientific investigations.

POE includes three main learning activities, namely Predict, Observe, and Explain. In its implementation, students are first asked to predict the results of a demonstration, event, or experiment, and explain the reasons for their prediction. Subsequently, the prediction results are written on the worksheet provided. In the next step, students conduct experiments and record the results of their observations systematically. The difference between the initial prediction and the observation results

became the basis for further discussion with colleagues in a team. Through this process, students are encouraged to analyze, revise, and provide explanations for the results of the predictions and findings obtained, then presented in front of the class. Learning activities carried out during POE are related to three stages that can improve metacognitive skills, as explained by Bae & Kwon (2021), including the pre-planning, planning, and post-planning adjustment stages. The first stage, the pre-planning stage, emphasizes reflection on the thinking process, including the task to be completed and previous strategies that promote or hinder its success. In the second stage, students develop and implement a plan for completing the task, and in the third stage, they analyze the implementation of the plan, evaluate it, and revise the plan. These three stages encourage students to understand their learning process and ultimately practice their metacognitive skills.

All the POE learning activities reflect the high active participation of students both physically and mentally during learning, thereby encouraging students to develop awareness in their learning process to self-monitor, plan, and reflect on their learning progress. It is supported by Novak (2002) that current learning theory emphasizes that students must actively participate in lessons, and that this participation is not only physical but also mental. In addition, Chen et al. (2025) emphasized in their study that POE is effectively able to facilitate deeper conceptual engagement and encourage reflective learning behaviors. Consequently, the individuals who can use metacognitive processes will find an easier way to think critically (Magno, 2010). Therefore, the contribution of metacognitive on critical thinking skills is greater in the context of POE learning than direct learning which tends to be more structured and instructional.

#### *Differences in metacognitive and critical thinking skills between students taught using guided POE and DI strategies*

The following descriptive statistical results show the average metacognitive and critical thinking scores in POE and DI learning (Table 7). The results in Table 7 show that the metacognitive skill score in the POE class was slightly higher compared to the DI class (0.77). Meanwhile, the difference in critical thinking scores between the two learning strategies is more striking, namely students in the POE class have a critical thinking score about 10 points higher than the DI class. This suggests that POE based learning is likely to be more effective in improving students' critical thinking skills than direct learning (DI). To ascertain whether there is a significant difference between the two classes, a test is carried out through a non-paired t-test as shown in Table 8.

**Table 7 Comparison of average metacognitive and critical thinking scores on POE and DI strategies**

|                   | Class | N   | Mean    | Std. deviation | Std. error mean |
|-------------------|-------|-----|---------|----------------|-----------------|
| Metacognitive     | DI    | 32  | 40.1219 | 12.20987       | 2.15842         |
|                   | POE   | 330 | 40.8930 | 18.39202       | 3.35791         |
| Critical thinking | DI    | 32  | 57.8750 | 8.56003        | 1.51321         |
|                   | POE   | 30  | 67.8667 | 12.31689       | 2.24875         |

**Tabel 8 Comparison in both groups through independent sample T-test**

| Group                                           | t-test for equality of means |    |                 |                 |                       |                                           |         |
|-------------------------------------------------|------------------------------|----|-----------------|-----------------|-----------------------|-------------------------------------------|---------|
| Metacognitive skills in POE and DI strategy     | t                            | df | Sig. (2-tailed) | Mean difference | Std. error difference | 95% confidence interval of the difference |         |
|                                                 | -0.196                       | 60 | .0846           | -0.77113        | 3.9413                | Lower                                     | Upper   |
| Critical thinking skills in POE and DI strategy | -3.729                       | 60 | .0000           | -9.99167        | 2.6797                | -15.3517                                  | -4.6315 |

Table 8 shows that the results of the t-test analysis of metacognitive skills in both classes showed a p-value of 0.846, greater than the value of  $\alpha$  (0.05). Findings from the study implied that there was no significant difference between the average metacognitive skill scores of the two groups that applied different learning strategies. On the other hand, the t-test analysis of critical thinking skills in both classes showed a p-value of 0.000, which is less than the value of  $\alpha$  (0.05). Thus, there is a significantly difference between the critical thinking skill score of the two groups with the POE learning model is more advantageous. Therefore, this clearly indicates that POE learning strategies are more effective than DI in improving critical thinking skills.

The absence of significant differences in metacognitive skills between the two learning methods may be attributed to the fact that, although the POE strategy explicitly supports metacognitive development, students in both groups were exposed to learning experiences that had the potential to foster metacognitive skills. DI also provides opportunities for students to develop metacognition through the question and answer process carried out with teachers and students, and through practical activities, although in a more limited form and less structured. These results align with findings of Ajayi & Achor (2021) that showed no significant difference in metacognitive awareness scores between the implementation of POE, VH, and discussion. The Vee Heuristic (VH) strategy is further explained as a learning method that directs students to create a V-shaped diagram to display key elements or ideas from conceptual knowledge on the left and methodological aspects on the right side as an effort to improve conceptual understanding of science concepts.

In addition, the findings of this study are also consistent with research conducted by Safitri et al. (2024) which found that the use of POE in biology learning can significantly improve students' critical thinking skills. Similarly, Alfianti et al. (2020) and Aulia & Yuliani (2023) found that the implementation of POE can improve students' critical thinking skills. Moreover, in its implementation, Alfianti et al.

(2020) used PhET as a form of experimental activity on abstract objects (kinetic gas theory).

The more exploratory and interactive nature of POE learning can explain significant differences in the critical thinking skills in POE classes. Making predictions that are useful for activating knowledge, identifying assumptions, and providing explanations verbally and in writing contributes to critical thinking skills (Willingham, 2007). Through the activities students undertake during the prediction stage, critical thinking skills can be developed when they can make assumptions about a problem. Therefore, students will attempt to deduce the main concept and then explore possible relationships between variables to predict the outcome of an experiment or problem presented. The inference and deduction skills practiced during the prediction stage are two important indicators that support critical thinking skills, as mentioned by Magno (2010).

Observing and providing explanations also encourages students to think deeply and critically about the information they learn. It is explained by Sadeghi et al. (2014) that critical thinking can be developed during classroom learning when teachers provide opportunities for students to process information in depth to monitor their knowledge and thinking processes. In this stage, students evaluate the correspondence between predictions and data and can also examine any discrepancies that may have arisen during the experiment. The results of these observations then serve as a basis for developing logical and scientific explanations for the experiments and concepts being studied. This activity also gives students the opportunity to revise their initial understandings, which may be inaccurate, based on existing scientific evidence and theory. The physical and mental activities developed during these two stages help train the ability to interpret and evaluate arguments, which are two other essential aspects of critical thinking skills.

Although metacognition plays a role in both types of learning, the characteristics of POE that encourage exploration and deep reflection are found to enhance critical thinking skills further. The relatively similar levels of metacognitive skills across

both groups suggest that each approach was equally effective in supporting metacognitive development. However, POE demonstrated a clear advantage in fostering critical thinking. While metacognitive processes are present in the implementation of the DI strategy, this approach does not appear to provide the same level of cognitive stimulation needed to promote higher-order thinking.

## D. Conclusion

Based on the results of the study, it can be concluded that there is a positive, strong, and significant relationship between metacognitive skills and critical thinking in both POE and DI implementations. In particular, the contribution of metacognitive skills to critical thinking was higher in POE compared to DI. An important insight found in this study is that metacognitive skills did not differ significantly between groups, despite clear differences in critical thinking performance. This may be explained by the fact that DI also provides space for metacognition. It is possible that POE promotes more reflective and strategic metacognition, whereas DI primarily fosters basic monitoring. This perspective could serve as a springboard for future research. In addition, it is recommended that educators adopt active and constructivist learning approaches, particularly POE strategies, to support the development of students' metacognitive and critical thinking skills.

## E. Acknowledgement

Thank you to Tidar University for supporting the implementation of this research through research grant No: B/176/UN57. L1/KS.00.00/2024.

## F. References

- Ajayi, V. O., & Achor, E. E. (2021). Is there any possibility of enhancing students' metacognitive awareness in chemistry in Ekiti state, Nigeria using predict-explain-observe-explain and vee heuristic strategies? A field report. *International Journal of Literacy and Education*, 1(1), 28–34. Retrieved from <https://ssrn.com/abstract=3873478>
- Akcaoglu, M. Ö., Mor, E., & Külekçi, E. (2023). The mediating role of metacognitive awareness in the relationship between critical thinking and self-regulation. *Thinking Skills and Creativity*, 47(July 2021), 1–11. DOI: <https://doi.org/10.1016/j.tsc.2022.101187>
- Aleven, V. A. W. M. M., & Koedinger, K. R. (2002). An effective metacognitive strategy: Learning by doing and explaining with a computer-based Cognitive Tutor. *Cognitive Science*, 26(2), 147–179. DOI: [https://doi.org/10.1207/s15516709cog2602\\_1](https://doi.org/10.1207/s15516709cog2602_1)
- Alfiyanti, I. F., Jatmiko, B., & Wasis. (2020). The effectiveness of predict observe explain (POE) model with PhET to improve critical thinking skills of senior high school students. *Studies in Learning and Teaching*, 1(2), 76–85. DOI: <https://doi.org/10.46627/silet.v1i2.34>
- Amin, A. M., Corebima, A. D., Zubaidah, S., & Mahanal, S. (2017, September). The critical thinking skills profile of preservice biology teachers in animal physiology. In *3rd International Conference on Education and Training (ICET 2017)* (pp. 179-183). Atlantis Press. DOI: <https://doi.org/10.2991/icet-17.2017.30>
- Andrini, V. S. (2016). The effectiveness of inquiry learning method to enhance students' learning outcome: A theoretical and empirical review. *Journal of Education and Practice*, 7(3), 38-42. Retrieved from <https://iiste.org/Journals/index.php/JEP/article/view/28416>
- Arslan, S. (2018). Investigating predictive role of critical thinking on metacognition with structural equation modeling. *MOJES: Malaysian Online Journal of Educational Sciences*, 3(2), 1-10. Retrieved from <https://jrmg.um.edu.my/index.php/MOJES/article/view/12690>
- Arslan, S., Akin, A., & Çltemel, N. (2013). The predictive role of grit on Metacognition in Turkish university students. *Studia Psychologica*, 55(4), 311–320. DOI: <https://doi.org/10.21909/sp.2013.04.645>
- Aulia, M., & Yuliani, H. (2023). POE-based e-module (predict, observe, and explain): Improving students' critical thinking skills on kinetic theory of gases. *Online Learning In Educational Research (OLER)*, 2(2), 57–66. DOI: <https://doi.org/10.58524/oler.v2i2.128>
- Bae, H., & Kwon, K. (2021). Developing metacognitive skills through class activities: What makes students use metacognitive skills? *Educational Studies*, 47(4), 456–471. DOI: <https://doi.org/10.1080/03055698.2019.1707068>
- Bahri, A., & Corebima, A. D. (2015). The contribution of learning motivation and metacognitive skill on cognitive learning outcome of students within different learning strategies. *Journal of Baltic Science Education*, 14(4), 487–500. DOI: <https://doi.org/10.33225/jbse/15.14.487>
- Butler, H. A., Dwyer, C. P., Hogan, M. J., Franco, A., Rivas, S. F., Saiz, C., & Almeida, L. S. (2012). The halpern critical thinking assessment and real-world outcomes: Cross-national applications. *Thinking Skills and Creativity*, 7(2), 112–121. DOI: <https://doi.org/10.1016/j.tsc.2012.04.001>
- Cakici, D. (2018). Metacognitive awareness and critical thinking abilities of pre-service EFL teachers. *Journal of Education and Learning*, 7(5), 116. DOI: <https://doi.org/10.5539/jel.v7n5p116>
- Chen, K. F., Hwang, G. J., & Chen, M. R. A. (2025). Precision diagnosis in virtual learning contexts: A predict-observe-explain-diagnose-based approach to scientific inquiry. *Educational technology*

- research and development, 1-28. DOI: <https://doi.org/10.1007/s11423-025-10527-5>
- Corebima, A. D. (2009, November). Metacognitive skill measurement integrated in achievement test. In *Third International Conference on Science and Mathematics Education (CoSMEd)* (Vol. 5, No. 1). Penang: SEAMEO Regional Centre for Education in Science and Mathematics.
- Corebima, A. D. (2016). Pembelajaran biologi di Indonesia bukan untuk hidup. In *Proceeding Biology Education Conference: Biology, Science, Enviromental, and Learning* (Vol. 13, No. 1, pp. 8-22). Retrieved from <https://jurnal.uns.ac.id/prosbi/article/view/5640>
- Creswell, J. W. (2019). Research design and mixed methods quantitative. Qualitative, approaches. In *Awkward Dominion* (Second Edition). SAGE Publications Ltd. DOI: <https://doi.org/10.7591/9781501721144-016>
- Drigas, A., Mitsea, E., & Skianis, C. (2023). Meta-learning: A nine-layer model based on metacognition and smart technologies. *Sustainability (Switzerland)*, 15(2), 1–19. DOI: <https://doi.org/10.3390/su15021668>
- Erdem Özcan, G., & Uyanık, G. (2022). The effects of the “Predict-Observe-Explain (POE)” strategy on academic achievement, attitude and retention in science learning. *Journal of Pedagogical Research*, 6(3), 103-111. DOI: <https://doi.org/10.33902/jpr.202215535>
- Flavell, J. H. (1979). Metacognition and cognitive monitoring: A new area of cognitive-developmental inquiry. *American Psychologist*, 34(10), 906–911. DOI: <https://doi.org/10.1093/nq/CLVII.dec14.424-a>
- Gurcay, D., & Ferah, H. O. (2018). High school students’ critical thinking related to their metacognitive self-regulation and physics self-efficacy beliefs. *Journal of Education and Training Studies*, 6(4), 125-130. DOI: <https://doi.org/10.11114/jets.v6i4.2980>
- Jin, M., & Ji, C. (2020). The correlation of metacognitive ability, self-directed learning ability and critical thinking in nursing students: A cross-sectional study. *Nursing open*, 8(2), 936-945. DOI: <https://doi.org/10.1002/nop.2.702>
- Kabeel, A. R., & Eisa, S. A. E. M. M. (2016). The correlation of critical thinking disposition and approaches to learning among baccalaureate nursing students. *Journal of Education and Practice*, 7(32), 91-103. Retrieved from <https://www.iiste.org/Journals/index.php/JEP/article/view/34108>
- Kozikoğlu, I. (2019). Investigating critical thinking in prospective teachers: Metacognitive skills, problem solving skills and academic self-efficacy. *Journal of Social Studies Education Research*, 10(2), 111-130. Retrieved from <https://www.jsser.org/index.php/jsser/article/view/362>
- Kuhn, D., & Dean, Jr., D. (2004). Metacognition: A bridge between cognitive psychology and educational practice. *Theory Into Practice*, 43(4), 268–273. DOI: [https://doi.org/10.1207/s15430421tip4304\\_4](https://doi.org/10.1207/s15430421tip4304_4)
- Liu, O. L., Frankel, L., & Roohr, K. C. (2014). Assessing critical thinking in higher education: Current state and directions for next-generation assessment. *ETS Research Report Series*, 2014(1), 1–23. DOI: <https://doi.org/10.1002/ets2.12009>
- Magno, C. (2010). The role of metacognitive skills in developing critical thinking. *Metacognition Learning*, 5, 137–156. DOI: <https://doi.org/10.1007/s11409-010-9054-4>
- Mall-Amiri, B., & Ahmadi, Z. (2014). The relationship between EFL learners’ critical thinking, and metacognitive strategies. *International Journal of Language Learning and Applied Linguistics World (IJLLALW)*, 5(1), 488–505. Retrieved from <https://www.academia.edu/download/32807267/pdf-paper.ijllaw.pdf>
- Maor, R., Paz-Baruch, N., Grinshpan, N., Milman, A., Mevarech, Z., Levi, R., Shlomo, S., & Zion, M. (2023). Relationships between metacognition, creativity, and critical thinking in self-reported teaching performances in project-based learning settings. *Thinking Skills and Creativity*, 50(June 2022), 101425. DOI: <https://doi.org/10.1016/j.tsc.2023.101425>
- Novak, J. D. (2002). Meaningful learning: The essential factor for conceptual change in limited or inappropriate propositional hierarchies leading to empowerment of learners. *Science Education*, 86(4), 548–571. DOI: <https://doi.org/10.1002/sce.10032>
- Räsänen, M., Postareff, L., & Lindblom-Ylänne, S. (2021). Students’ experiences of study-related exhaustion, regulation of learning, peer learning and peer support during university studies. *European Journal of Psychology of Education*, 36(4), 1135–1157. DOI: <https://doi.org/10.1007/s10212-020-00512-2>
- Sadeghi, B., Hassani, M. T., & Rahmatkhah, M. (2014). The relationship between EFL learners’ metacognitive strategies, and their critical thinking. *Journal of Language Teaching and Research*, 5(5), 1167–1175. DOI: <https://doi.org/10.4304/jltr.5.5.1167-1175>
- Safitri, N., Agnafia, D. N., & Anfa, Q. (2024). The effect of the predict observe and explain learning model on critical thinking ability of junior high school students on environmental pollution. *BIO-INOVED : Jurnal Biologi-Inovasi Pendidikan*, 6(1), 119-124. DOI: <https://doi.org/10.20527/bino.v6i1.16268>
- Saputri, W. (2017). Keterampilan metakognitif mahasiswa calon guru dan hubungannya dengan pola pembelajaran dosen. *Didaktika Biologi: Jurnal*

- Penelitian Pendidikan Biologi*, 1(2), 113-121. DOI: <https://doi.org/10.32502/dikbio.v1i2.688>
- Semerci, Ç., & Elaldi, Ş. (2014). The roles of metacognitive beliefs in developing critical thinking skills. *Bartın Üniversitesi Eğitim Fakültesi Dergisi*, 3(2), 317-317. DOI: <https://doi.org/10.14686/buefad.201428187>
- Taghva, F., Rezaei, N., Ghaderi, J., & Taghva, R. (2014). Studying the relationship between critical thinking skills and students' educational achievement (Eghlid Universities as case study). *International Letters of Social and Humanistic Sciences*, 25, 18-25. DOI: <https://doi.org/10.18052/www.scipress.com/ilshs.25.18>
- Tuononen, T., Hyytinen, H., Räisänen, M., Hailikari, T., & Parpala, A. (2023). Metacognitive awareness in relation to university students' learning profiles. *Metacognition and Learning*, 18(1), 37-54. DOI: <https://doi.org/10.1007/s11409-022-09314-x>
- Vezzosi, M. (2004). *Critical thinking and reflective practice: The role of information literacy*. Education. Retrieved from <https://www.researchgate.net/profile/Monica-Vezzosi/publication/33436298>
- Warni, W., Sunyono, S., & Rosidin, U. (2018). Measuring metacognitive ability based on science literacy in dynamic electricity topic. *IOP Science: Journal of Physics: Conference Series* (Vol. 948, No. 1, p. 012041). IOP Publishing. DOI: <https://doi.org/10.1088/1742-6596/948/1/012041>
- Zarzycka, D., & Gesek, M. (2022). The factors affecting the critical thinking skills among nursing students- An integrative literature review. In *Pielegniarstwo XXI Wieku* (Vol. 21, Issue 3, pp. 174-180). Sciendo. DOI: <https://doi.org/10.2478/pielxxiw-2022-0021>
- Zubaidah, S., Corebima, A. D., & Mistianah, M. (2015, April). Asesmen berpikir kritis terintegrasi tes essay. In *Symbion: Symposium on Biology Education* (pp. 200-213). Retrieved from <https://www.researchgate.net/publication/322315188>