



Implementation of PBL-TaRL to Explore Students' Scientific Explanation in Ecosystem Topics

Findyta Novia Ferosa¹, Rusdi Hasan², Akhmad Sukri³, Marheny Lukitasari^{4*}

^{1,4}Department of Pendidikan Profesi Guru, Universitas PGRI Madiun, Indonesia

²Universitas Padjadjaran, Indonesia

³Biology Department, Universitas Pendidikan Mandalika, NTB, Indonesia

*lukitasari@unipma.ac.id

Abstract. The aim of this study is to analyze the impact of Problem-based Learning on the Teaching at the right level (PBL-TaRL) implementation on students' Scientific Explanation (SE) and understand the students' perceptions on the implementation of PBL-TaRL. In this research, a sequential explanatory mixed-method design was used. In order to obtain quantitative data, one group pretest-posttest design was used. The participants consist of 10th-grade students studying in a high school in Madiun, East Java. Students' SE skills and student perceptions of this approach were analyzed through SE tests, questionnaires, and non-participant observation. The results of the study revealed that the implementation of PBL-TaRL leads to a significant differentiation in the students' SE skills. The data obtained from qualitative processes also confirm this. In addition, it shows that the practice has a statistically meaningful effect on their knowledge acquisition toward the topic. The data obtained from the qualitative processes have proved that the implementation is influential in the emotions such as happiness, joy, excitement, pride and that the students considerably support the use of this implementation.

Keywords: Problem Based Learning, Scientific Explanation (SE), TaRL, Ecosystem

1 Introduction

The development of scientific explanation (SE) plays an important role in contemporary education as it helps learners acquire 21st century skills. Students' involvement in the crafting of SE may help them develop a good attitude toward science and improve their understanding of scientific concepts (Goh, 2017; Gotwals, et al., 2012). Understanding what constitutes evidence, recognizing the components of SE, and understanding how the pieces fit together into a coherent whole are all key facets of developing scientific literacy (Gotwals, et al., 2012; NRC, 2007). Moreover, analyzing arguments, judging, evaluating, reasoning, and deciding the evidence can cover critical thinking aspects (Shaughnessy et al., 2017; Suhartoyo, 2017). Finally, developing SE is a critical step toward obtaining scientific literacy and critical thinking in order

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to create a society that is capable of solving challenges and making accurate judgments regarding global issues in the 21st century (Steven, et al., 2013). These skills are crucial not only for scientists but for all individuals as a generic skill (Virtanen, 2018). Consequently, we are interested in supporting all students in constructing SE.

However, the facts show that the development of SE in science education, particularly biology education, is still not optimal (Driver, 2000; Duschl, 2002; Krajcik & McNeill, 2015; McNeill, et al., 2007; Yao & Guo, 2018; Yao, et al, 2016). Prior research in science classrooms also indicates that students struggle to construct high-quality SE (McNeill & Krajcik, 2006). According to studies, the ability to construct SE does not come readily to most individuals; rather, it is largely acquired by practice (Goh, 2016). As a result, students should be explicitly taught the skill to construct appropriate SE, and it should be practiced regularly in science classrooms.

Indonesian teachers need to acknowledge the importance of developing students' SE as their practices play a crucial role in students' understanding and use of SE (Lizotte, et al., 2004). Recently, Indonesian teachers have begun to implement the Merdeka curriculum in their classrooms as per the directions from the Indonesian government. They have embraced the opportunity to help their students build crucial general skills, like SE skills. One notable characteristic of the Merdeka Curriculum is its inherent flexibility. The flexibility of the curriculum is attributed to its ability to be adjusted in order to suit the diverse needs and interests of students. Synchronizing instructional practices with students' current level of achievement, rather than their assigned grade level is crucial. The approach referred to Teaching at the Right Level (TaRL) has been recognized for its effectiveness in improving learning skills. This effectiveness has been supported by rigorous evaluations (Ahyar, et al., 2022; Banerjee et al., 2016; Cahyono, 2022; Jazuli, 2022; Mubarokah, 2022).

Merdeka Curriculum also emphasizes the use of problem-based learning (PBL) in teaching and learning practices. PBL is a type of inquiry-based learning that has many methodological traits in common with other inquiry-based learning approaches, including involving students in real-world tasks, working in small groups, placing students at the center of the learning process, processing multiple information sources, using teachers as learning facilitators, simulating professional situations, and utilizing peer evaluations. In PBL, learning is driven by the students' inquiries since they must approach a complicated problem through inquiry to comprehend it well. As they can be crucial for transforming from a passive to an active learning process, working on real-world problems in a collaborative manner, and giving opportunities to teachers for facilitating students with SE explicit framework and modeling in its syntax, therefore this learning model is thought to be the ideal instrument for promoting students' SE (Gotwal, 2012, Goh, 2016; Tilbury, 2011; Lozano et al., 2017).

Acknowledging the study conducted before, the explicit explanations about scientific inquiry practices and providing students with different heuristics cases are significant to help learners understand and use SE. More specifically, there are several characteristics of teachers' classroom practice that are important to develop students' understanding of SE's components (McNeill, et al., 2006; Lizotte, 2004). Firstly, demonstrating the model of SE construction. Secondly, inviting students to become critical to the SE construction model. Thirdly, providing students with an SE frame-

work and the rationale behind that framework. When we examine the previous research, we find out that very few research investigating this topic. Thus, the impact implementation of PBL-TaRL on students' SE and students' perception of their learning experience will be examined in this research. In this context, this research is considered to contribute to the related literature.

2 Methods

2.1 Study design

This sequential explanatory mixed-method study was done by collecting quantitative and qualitative (Actas, 2019). PBL-TaRL scenarios were designed and implemented in face-to-face learning and in Biology subject: Ecosystem. The process of the study is presented in Table 1.

Table 1. One group pretest-posttest design

Group	Pre-test	Process	Post-test
G	O ₁	X	O ₂

The scenario of this study used PBL combined with TaRL. The PBL syntax consists of 5 steps (Llach, 2023). The implementation of TaRL in this study took place in the study groups and students' worksheets. Researchers divided the students into 4 lower-level groups and 4 higher-level groups which are each group consisting of 3-5 students. The worksheet for lower-level students was different from the worksheet for higher-level students. Lower-level worksheets facilitated students with scaffolding (explicit SE framework). This intervention was carried out over three 2-hour sessions.

2.2 Participants

Participants in this study were 32 ten graders aged 15–16 years old at a high school in Madiun, Jawa Timur, Indonesia. They consisted of 10 male students (31.25%) and 22 female students (68.75%). This research was carried out in the second semester of the academic year 2022-2023.

2.3 Data collection

The collection of data was facilitated by three primary instruments: pre- and post-intervention SE tests, and post-intervention questionnaires. In order to enhance the existing data, the researcher conducted observations of problem-based learning (PBL) sessions and documented their observations in field notes. These field notes were then cross-referenced with the other collected data to ensure triangulation. Table 2 presents an overview of the data collection methodology employed in this study.

Table 2. Data collection

Instrument		Data collected
Pre-intervention	SE pre-test	<ul style="list-style-type: none"> • Students’ SE skills after the PBL-TaRL intervention
PBL-TaRL Implementation	Observations	<ul style="list-style-type: none"> • How do students construct SE during the PBL-TaRL session? • How does the group session develop?
Post-intervention	SE post-test	<ul style="list-style-type: none"> • Students’ SE skills after the PBL-TaRL intervention
	Questionnaire (student self-reflection)	<ul style="list-style-type: none"> • Students’ perception of their knowledge about topics after the PBL-TaRL intervention • Students’ perception of their skill in SE after the PBL-TaRL intervention • Students’ perception of the implementation of PBL-TaRL.

2.4 Instrument

SE pre-test and post-test

To gather evidence of the students’ SE construction skills, the researcher analyzed the student task using the SE test before and after the intervention. The SE test instrument consisted of five open-ended questions to reveal the students’ construction skills of claim, evidence, and reasoning (Krajcik, et al., 2016; Songer and Gotwal, 2012). Based on these components, then SE test blueprint was given for each component in Table 3. The instrument of this study was valid and reliable. The validity and reliability of instruments were obtained using the RASCH measurement model (Adams, et al., 2021; Sumintono & Widhiarso, 2014).

Table 3. SE test blueprint

Component	Code of Component	Code of Question
Claim	C	C1, C2, C3, C4, C5
Evidence	E	E1, E2, E3, E4, E5
Reasoning	R	R1, R2, R3, R4, R5

(Krajcik, et al., 2016; Songer and Gotwal, 2012)

Questionnaire

To reveal the students’ perceptions of PBL-TaRL implementation and their learning, questionnaires were given to students. The questionnaire had three parts: (1) knowledge acquisition related to the Ecosystem topic; (2) SE skills; and (3) reflection about their feelings towards the PBL-TaRL learning experience.

Observations

We employed classroom observations during the implementation of PBL-TaRL. The observers followed a structured-observational sheet to record students’ non-

verbal behavior and behavior in the classroom setting. Four questions were generated to measure students' engagement (e.g., to what degree of attention, curiosity, interest, optimism, and passion that students show when they are learning or being taught?), and students' difficulties (e.g., Do you think that the students find it difficult to learn?).

2.5 Data analysis

The quantitative data were subjected to analysis using the Statistical Package for the Social Sciences (SPSS). In order to conduct a comparison between the results of SE pre-test and post-test, the responses were categorized based on group and gender. Subsequently, a paired samples t-test was employed to compare the means, assuming a normal distribution (Norman, 2010).

The qualitative content of the responses were analyzed using manual coding (Saldana, 2010). The researcher engaged in an iterative process to establish and enhance the ultimate codes and categories that effectively encapsulate the data (Elo et al., 2014). The researcher initially employed an inductive approach to identify emerging topics and concepts. Subsequently, the researcher conducted a comprehensive analysis of data sources to identify patterns both across and within them. Finally, the researcher established codes and categories to further refine the analysis (Bingham and Witkowsky, 2022; So & Hu, 2019).

3 Result and Discussion

This section is organized based on the purposes of the present study. First, we strived to analyze the impact of the implementation of PBL-TaRL on students' SE. Regarding this, we display the results of the SE pretest and posttest, students' self-reflection, and classroom observation. Secondly, this study aims at understanding the students' perceptions toward the implementation of PBL-TaRL.

3.1 Results

3.2 Impact of PBL-TaRL Implementation on students' scientific explanation

The t-test results on pre-test and post-test show that Sig. value more < 0.05 , so it means that there is significantly different score on students' SE before and after PBL-TaRL intervention (Table 4).

Table 4. Independent Samples T-Test

		Levene's Test for Equality of Variances		t-test for Equality of Means					95% Confidence Interval of the Difference	
Score	Equal variances assumed	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
			1	.681	.413	-10.115	62	.000	1.03188	.10201
	Equal variances not assumed			-10.115	59.624	.000	1.03188	.10201	1.23596	.82779

Table 5 displays the values representing the SE abilities of students both before and after the intervention. The scores provided by the students exhibited a notable increase across all items pertaining to SE in the post-intervention surveys as compared to the pre-intervention surveys. As shown in Table 5, the three indicators of SE with claim (M=3.63, SD=0.48), evidence (M=3.25, SD=0.43), and reasoning (M=2.78, SD=0.48) have shown a statistically significant increase.

Table 5. Students SE score

Component	Pre-intervention		Post-intervention	
	M	SD	M	SD
Claim	2.69	0.68	3.63	0.48
Evidence	2.16	0.44	3.25	0.43
Reasoning	1.72	0.51	2.78	0.48

M= Means, SD= Standard Deviation

The students were also asked to reflect on their SE through the self-reflection worksheet. The results of the reflection were in line with that of the SE test. In the pre-intervention, the majority of the students perceived that they were not fully able to deliver appropriate claims (N=10), support them with relevant shreds of evidence (N=21), and make sense of the relationship between the claims and evidence (reasoning) (N=27). However, the student’s perception of their ability to compose SE (Claim, N=30; Evidence, N=26, and Reasoning, N=24) increased significantly after the intervention.

3.3 Discussion

Based on the implementation of PBL-TaRL intervention, we reveal that the use of PBL-TaRL has a positive impact on students’ SE. PBL-TaRL offers a range of activi-

ties allowing students to engage in the real-world, up-to-date and transversal problems. These activities help students to cultivate skills contributing to SE such as systemic and normative thinking, integrated problem-solving and self-awareness skills (Frisk and Larson, 2011; Corres, 2020). The analysis also shows that students would construct stronger explanations as teachers explicitly defined the conceptual framework of SE and its components (i.e. claim, evidence, and reasoning explicitly).

Moreover, the overall experience of the observation and students' self-reflection showed that the PBL-TaRL is a great tool for fostering students' SE. Students looked more confident and fluent in expressing their ideas. They also include relevant evidence to support their ideas. These results also can be observed on students SE tasks (Figure 1).

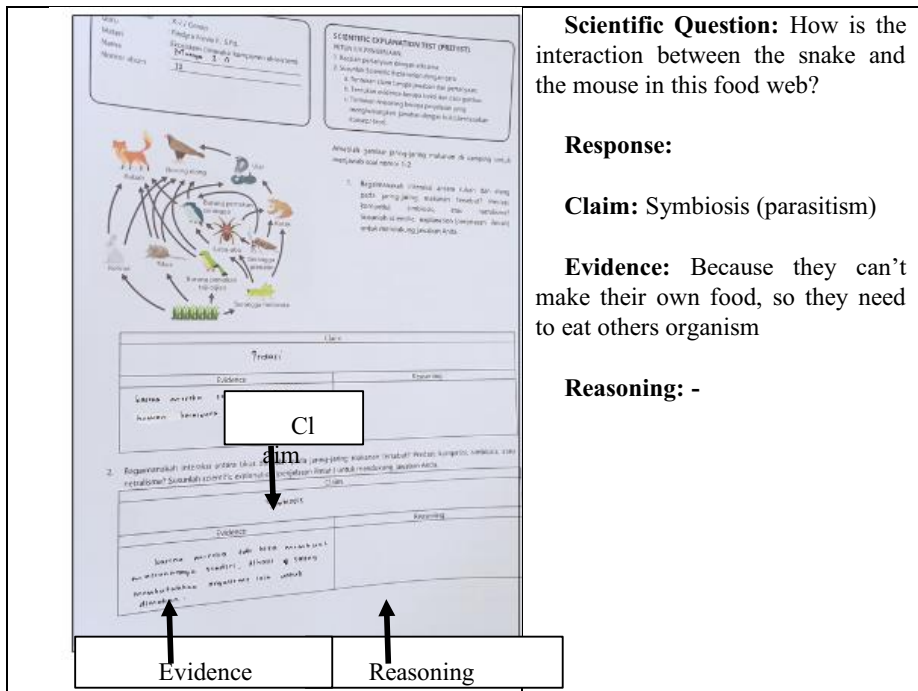


Fig. 1. Students' SE task in Ecosystem topic before PBL-TaRL intervention

Figure 1 showed that before PBL-TaRL implementation, students from lower-level groups have difficulty constructing high-quality SE. Students from lower-level groups struggles with constructing claim and evidence, but have more difficulty with the reasoning. Based on this fact, we suggest that it may be significant to consider a scaffolding in their worksheet in order to support the students' SE.

Scientific Question: How is the interaction between the snake and the mouse in this food web?

Response:

Claim: Predation

Evidence: Because the snake eat the mouse

Reasoning: Its interaction shows feeding behavior, one species feeds on another for its survival.

Fig. 2. Students' SE task in Ecosystem topic after PBL-TaRL intervention

Figure 2 showed that PBL-TaRL implementation helps students from lower-level groups to construct high-quality SE. The improvement of students' SE can also be seen in the result of classroom observation. The results said that the development of students' SE is obvious during the intervention of PBL-TaRL.

Unlike in the previous meeting, in this meeting, students looked more confident and fluent in expressing their ideas. They also include relevant evidence to support their ideas. (O-1)

Students from lower-level groups are helped by TaRL worksheets that facilitate scaffoldings (Gotwal and Songer, 2012; Krajcik, 2006; Tabak, 2004). Finally, lower-level students can construct SE as well as higher-level students. Moreover, students' self-reflection showed that they can construct claim and evidence easier than construct reasoning (Krajcik, 2018).

Students perceptions about the PBL-TaRL learning experience.

The assessment of the students' PBL-TaRL learning experience involved qualitative methods, which included analyzing the students' self-reflection and conducting post-intervention interviews. After analyzing all the data, we identified three themes:

(1) PBL-TaRL activities, (2) the learning process, and (3) satisfaction, limitations, and suggestions.

Students perceptions of PBL-TaRL activities.

The first theme pertained to the perspectives of students regarding the design of PBL-TaRL activities. The students expressed a positive response to the scenarios, describing them as appealing, innovative, relatable, and imaginative, which led to their appreciation of the presentation style.

I liked how it was put together a lot. It made us want to know more. It was striking and made you think more about what you were learning. It was also interesting. (SR-1)

The proposed topic elicited a significant level of student engagement due to its inherent interest and direct relevance to the students.

I think the learning activities were very engaging and they totally had an impact on me. I was highly dedicated and motivated. (SR-2)

The students hold the belief that the incorporation of SE materials in their learning experiences has facilitated the development of their SE skills, aided in the contextualization of scientific concepts, provided enrichment, heightened awareness, alleviated monotony, and offered a comprehensive understanding of the problem at hand. Nevertheless, a subset of students experienced a slight sense of being overwhelmed due to the multitude of sub-themes.

This work really opened my eyes. We looked at it from different angles and ended up learning a bunch. Usually, I wouldn't have gotten involved, but somehow I ended up in the middle of it and became super self-aware of how to show it. (SR-3)

Students perception of the learning process.

This theme related to the students' perception regarding the teacher, the evaluation process, and the group dynamics. Overall, the teacher was perceived as supportive and guiding. However, some students argued that having knowledge of the teachers' expectations regarding specific learning outcomes hindered their curiosity and originality. While some students expressed satisfaction with the evaluation process, others believed that the assessment did not adequately recognize the importance of originality. The perception of the group dynamics varied among students. While some students were highly satisfied, others felt that there was a lack of collaboration and efficiency.

You know how the teacher has these very specific learning goals, right? And then they grade you based on how well you

meet them. I'd rather have objectives that are more open and let people explore what they're most into. (SR-4)

Students satisfaction, limitations, and suggestions.

Under this theme, we compiled the key findings that led to student satisfaction with the teaching activities, as well as suggestions for improving certain aspects. Students were generally pleased with the PBL-TaRL approach. According to the students, it broadened their comprehension of the topic and enhanced their SE and knowledge acquisition. Students identified a lack of time and a large quantity of information to be assimilated as constraints. They suggested that more time should be allocated for group discussions and that students should be encouraged to implement their knowledge in realistic simulations, such as debates and seminars.

I think it's quite an interesting topic and definitely worth discussing. The scenario's format was totally perfect. (SR-5)

It was a really interesting but also quite lengthy topic, so I wish I had more time. (SR-6)

Maybe we should do something to get more people to know about this topic. (SR-7)

The inclusion of TaRL in PBL provides students with opportunities to discuss and reflect on their group. TaRL implementation in this research is located on students' group discussion and students' worksheets. These practices covered the SE stimulating activity through SE explicitness framework and modeling SE (Gotwal, 2016; Jazuli, 2022; Krajcik, 2016). Making the SE framework explicit to students helps facilitate students' understanding of SE and use of these skills. It also might support diverse learners who are more likely to be unfamiliar with the SE conceptual framework. As a result, these features of TaRL may allow students with restricted SE experiences to more actively participate in biology classroom teaching and learning as well as be beneficial to all students (Akhyar, 2022; Cahyono, 2022).

4 Conclusion

The purpose of this research is to examine the impact of the use of PBL-TaRL on students' SE skills and to understand students' perception of the learning experience. This research reveals that the use of PBL-TaRL in Ecosystem topics has a positive impact on students' SE. Furthermore, the use of PBL-TaRL in Biology subject has a positive effect on students' perception toward their learning experience. Students experienced positive feelings such as joy, happiness, and excitement during the implementation of PBL-TaRL. As a result, the PBL approaches described in this research demonstrate a pedagogical approach that high schools can employ to train students' SE skills. The research's findings offer not only support for this evidence

but also guidance and strategies for successfully implementing such techniques into practice. In the end, we hope it will serve as a model and inspire the teaching community to join us in fulfilling this urgent, and crucial task of educating for SE development.

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