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Experimental analysis of PBL-POE integration in science education to foster critical thinking in young learners

Anisa Wahyu Kusumaningtyas[1*], Candra Utama[2], Yohannes Kurniawan Barus[3]
[1, 2, 3] Faculty of Education, Universitas Negeri Malang, Indonesia
**Corresponding email: anisakusumaningtyas1@gmail.com*

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ABSTRACT

The integration of the PBL and POE models (PBL-POE) is claimed to be superior to the PBL model. The PBL-POE model is good in science because it can combine problems and experiments at the same time, where experiments are the heart of science learning. This is certainly suitable for empowering 21st-century skills, such as critical thinking. Having 21st-century skills is now a necessity for students. Critical thinking is a way of thinking that influences someone in making informed decisions regarding problems faced and conducting reflective evaluations. Using a quasi-experimental approach, this study aims to explore the effectiveness of the PBL-POE model on the critical thinking skills of elementary school students. This study used 52 students who had problems related to critical thinking skills. Data were collected in the form of essay test questions. The data analysis technique used to answer the research objectives was the Cohen's d effect size test. The results of the PBLPOE model effectiveness test on Cohen's d effect size were 1.105. These findings indicate that the PBL-POE model is significantly more effective in improving critical thinking skills. Therefore, the PBL-POE model should also be tested on other variables such as science process skills, and others.

INTRODUCTION

According to several studies in the article Almasri, (2024), science education aims to create a scientifically literate population that can use scientific reasoning and decision making in addition to providing scientific information. The implications of this goal can be seen in science education in a country. Science education in this study focuses on science learning on force material. However, the results of science learning on force material in one city in Indonesia were slightly lacking. In several elementary schools in Blitar City, misconceptions were still found on force material (Kusumaningtyas, Meydawati, et al., 2025; Raysalma et al., 2025). This indicates that in the material, learning is needed that is more than just an experiment. Because the core of teaching and learning in science classes is experimental science and direct practice (Moore et al., 2020). Therefore, it is necessary to combine experiments with problems supported by the method of making hypotheses from the beginning of education for young elementary school students.

This study tests the integration of the problem based learning (PBL) model with predict observe explain (POE) or better known as PBL-POE (Fitriani, 2020) in science learning, material on force in elementary schools. The PBL-POE model was developed because PBL could not improve scientific attitudes and the POE model had no effect on critical thinking skills (Fitriani, 2020). This study focuses on critical thinking, so researchers look more at the shortcomings of the POE model. In several studies, the POE model is also considered not good enough when compared to other learning models for critical thinking skills in the 21st century (Fitriani et al., 2020a; Husna & Pranoto, 2024; Setyaningrum et al., 2021). Therefore, development by integrating the PBL model with POE is very suitable because it supports 21st century learning. PBL-POE offers students to solve a current problem (Fitriani, 2020) and can be integrated with experiments. In this study, actual problems are integrated with scientific problems in the material of force. This is important to test because scientific problems are closely related to critical thinking skills and the use of experiments as the heart of science learning (Moore et al., 2020; Sidiq et al., 2021).

Critical thinking skills development is also supported by the learning theory that underpinned the development of the PBL-POE model. The PBL-POE model was born from three learning theories, namely two constructivism theories and information processing theory (Fitriani, 2020). Constructivism used in the birth of the PBL-POE model belongs to Vygotsky and Piaget. This is because many learning activities in the PBL-POE model illustrate this theory, such as collaboration, experiments, use of concrete objects, etc. Constructivist methods in teacher education can successfully prepare educators for inclusive and culturally diverse classrooms (Muhammad & Liu, 2025). This is also in accordance with the cultural diversity in Indonesia, because in one class there are students with diverse cultures, religions, races, etc. The PBL-POE model theory can also explain why critical thinking is also closely related to decision making, especially when facing problems in learning.

When making decisions, a person's knowledge is influenced by their understanding of perspectives. In the decision-making process that is based on several pieces of information and to overcome a complex problem, it also requires critical thinking (Astawan et al., 2023). Critical thinking is known as reasonable and reflective thinking with an emphasis on decision making (Ennis, 2011). Critical thinking also involves assessing the epistemic quality of available information and making decisions based on that assessment, which will be used to calibrate one's confidence in acting on that knowledge (Pasquinelli et al., 2021). When someone acts, it is the same as making a decision. From several definitions, it can be interpreted that critical thinking is a way of thinking that influences someone in making a decision based on information on the problems faced and evaluating which is done reflectively.

Evaluation is closely related to critical thinking. According to Bloom's taxonomy, critical thinking falls between cognitive levels C4 and C5 (Saraswati & Agustika, 2020). Both cognitive levels are closely related to analyzing and evaluating. Higher Order Thinking Skills (HOTS) include critical thinking. Bloom in 1956 wrote that several other Higher Order Thinking Skills (HOTS) are the basis for the complete critical thinking process (Thornhill-Miller et al., 2023). Critical thinking skills are also one of many forms of higher-order thinking that are closely related, along with decision-making, creative thinking, and problem solving (Facione, 1990). The use of this problem is closely related to the PBL-POE model. It can serve as a substitute for strengthening critical thinking skills. This is significant since skills in critical thinking are valued in kids' futures and should be held by all of us. In addition, using critical thinking in students who learn can solve difficulties more independently, creatively, and innovatively (Hidayat et al., 2023). One of the 4Cs and a 21st century competence is critical thinking. These 4Cs are also often known as soft skills (Thornhill-Miller et al., 2023). So students must acquire 21st century skills, both now and in the future (Benek & Akcay, 2022).

The world has witnessed tremendous and rapid changes, both in technology and culture since the turn of the 21st century (Care et al., 2024). Teaching 21st century skills in schools is necessary so that students can prepare for the future and make the transition to adulthood (Herianto et al., 2024). To be able to know the 21st century skills of a country, it is also seen from PISA and TIMSS. PISA evaluates the knowledge and skills needed in modern society rather than curriculum-based knowledge (Pulkkinen & Rautopuro, 2022). Comparison of PISA results in 2022 with 2018 in Indonesia showed a decline in all aspects tested (OECD, 2023). However, if we look at the ranking results with countries that took part in PISA in 2022 compared to 2018, Indonesia experienced an increase in ranking of 5-6 positions (Kementerian Pendidikan, 2023). This means that Indonesia has successfully overcome learning loss due to the pandemic. This also has an impact on the curriculum that Indonesia is currently using. Meanwhile, Indonesia last participated in TIMSS in 2015 and was ranked 44th out of 49 countries (Wijaya, 2017). The low PISA and TIMSS scores prompted researchers to conduct a preliminary study to find out more details regarding among the 21st century's competencies being studied.

21st century abilities include the ability to think critically measured in this study. These skills were chosen because students have not mastered them and can be empowered with the PBL-POE model through its activities. According to preliminary investigations in this study, less than half of the study population had this problem. This was determined by administering a critical thinking skills test to students. In actuality, Indonesia has encouraged critical thinking skills through the Pancasila Student Profile in the Merdeka curriculum. Critical thinking is one of the six traits required of students by the Pancasila Student Profile (Sutrisno et al., 2023). These six dimensions show that the Pancasila Student Profile places equal emphasis on cognitive skills as well as attitudes and behaviors that stem from their

identities as world citizens and Indonesian citizens (Widana et al., 2023). However, the sample in this study did not have such conditions.

Students that struggled with critical thinking were the subjects of the trials in this study. The preliminary research's findings also demonstrated that these issues were present among the study sample's students. In fact, the Merdeka curriculum has facilitated critical thinking skills and teachers have also carried out learning that leads to student-centeredness. In this study, teachers often use experimental methods with various learning models. However, in the material on style, the existing teaching modules do not link the material to real problems in the world. Where this is closely related to scientific problems and is related to students' critical thinking skills (Sidiq et al., 2021). This research sample's teachers all employ the Quantum Learning approach in their lesson plans. Actually, the modules that the teacher has already support the existing curriculum and can achieve the desired learning objectives. Higher Order Thinking Skills (HOTS) have not yet been attained as a result of the learning objectives in the training modules that the instructor developed. A component of critical thinking skills is HOTS itself. Although the teacher's module is excellent and connects to the student center, the PBL-POE model still needs to be tested. Testing two learning models that both lead to the student center in this study is certainly very interesting. Because it is possible to ascertain from the findings which learning model best fosters students' capacity for critical thinking.

Based on the ideal conditions and different realities, then testing the PBL-POE model on critical thinking skills is necessary because it is supported by activities that trigger critical thinking. In addition, numerous earlier research have likewise had a favorable effect on the PBL-POE model (Fitriani, 2020; Fitriani et al., 2019, 2020b, 2020a, 2020c; Perdanasari et al., 2022). Although the positive impact of the PBL-POE model has been widely studied, there has been no research on the impact of this model in elementary schools on critical thinking skills. The PBL-POE model can be an alternative for teachers in empowering students' critical thinking skills. This study is unique because it uses a variety of data analysis techniques and has different sample characteristics from several previous studies on PBLPOE and critical thinking (Fitriani et al., 2020a, 2020b; Perdanasari et al., 2022). This undoubtedly influences the choice of tools, materials, etc. This study has the goal to be achieved, namely to determine the effectiveness of the PBL-POE model on the critical thinking skills of elementary school students. Nonetheless, Quantum Learning is the conventional paradigm used in this investigation. Similar to PBL-POE, this concept also leads to the student center. Thus, the following are the research questions.

1. Did the experimental class's critical thinking skills change before and after the PBL-POE model was introduced into science learning?
2. Did the use of the conventional approach, namely Quantum Learning, in science learning in the control group change students' critical thinking skills both before and after?
3. How effective is the PBL-POE model on the critical thinking skills of elementary school students?

METHOD

Research Design

This study uses a quantitative approach of the Quasi Experimental type with Nonequivalent (Pretest and Posttest) Control-Group Design. This design was chosen because the researcher could not fully control the independent variables of the study. In addition, the researcher also did not need to mix classes to form new classes used in the study. Table 1 presents the research design with Nonequivalent (Pretest and Posttest) Control-Group Design adapted from Creswell & Creswell, (2018).

Table 1. Research Design

Group	Pretest	Treatment	Posttest
A	O	X	O
B	O	-	O

Information:

A : Treatment in the PBL-POE Model

B : No treatment given (conventional learning (quantum learning)).

Participant

The researcher needs to find schools that have problems related to critical thinking skills in Blitar City. The researcher randomly selected elementary schools in Blitar City as the research population. All of the students in the research sample made up the study's population. This is to save time because not all elementary schools have problems related to critical thinking skills. The students involved in this study were in grade 4 of elementary school. This research was conducted in February 2025 in the 2024/2025 academic year. This study is voluntary and anonymous for all participating students and their schools. Official permission has also been obtained from the schools participating in the study. This study involved 52 students aged 10-11 years. The saturated technique was used for sampling in this investigation. Each class in this study sample consisted of 26 students.

Data Collection

Data was collected using test instruments. The test in this study was used to determine critical thinking skills. The test in this study used essay questions made with critical thinking indicators used. The essay questions made to test critical thinking skills in this study only focused on style material. Table 2 is the grid of the test instrument used in this study.

Table 2. Test Instrument Grid

Indicators	Sub Indicators	Question Indicators
Basic clarification	Analyze arguments	Given an argument, students are able to identify the strongest reason/premise for the conclusion in the material on force.
	Focus on question	Presented with a picture, students are able to apply the skill of formulating questions and answers using the concept of force.
Bases for a decision	Judge the credibility of a source and ability to give reasons	Given a statement, students are able to assess its truth accompanied by scientific reasons using the concept of force.
Inference	Deduction	Presented with premises, students are able to relate them by using the conjunction "if then" appropriately to the material on force.
	Induction	Presented with data/cases, students are able to draw correct conclusions about solutions to the material on force.
Supposition and integration	Making and considering decisions	Presented with a problem, students are able to defend the decision-making process taken appropriately.
Auxiliary abilities	Strategies and tactics (actions) used in solving a problem	Presented with a simple problem, students are able to determine actions to solve the problem well.

Data Analysis

Based on the objectives and research questions proposed, this study has 2 main tests, namely the paired t-test and the Cohen's d effect size test. The paired t-test is used to answer research questions 1 and 2, regarding the differences in critical thinking skills before and after the learning model. This test was conducted using SPSS 26. This test has a prerequisite, namely normality. Normality in this study uses the Shapiro-Wilk test because the number of samples in this study is small. This is also done in several studies (Sidiq et al., 2021; Widyawati et al., 2024). Then, for the third research question regarding effectiveness, the Cohen's d effect size test was carried out.

Cohen's d effect size test, conducted after there is a difference between the two experimental and control classes. An unpaired t test, also known as an independent t test, is used to perform this

difference test. Normality and homogeneity tests are prerequisites for this test. The paired difference test and the normalcy test are the same in this case. SPSS 26 is used in the administration of this exam. The efficacy test is conducted if the difference is known. This difference test is measured through manual calculations with the existing formula. This study uses two groups with the assumption that populations are normal; homogeneity of variances. So with this information and assumption, the formula according to Cohen's d effect will be used (Goulet-Pelletier & Cousineau, 2018). Then the results were categorized according to Cohen in 1988, namely small (0.20), medium (0.50), and large (0.80) (Herianto et al., 2024).

Validity and Reliability

A critical thinking skills essay test instrument with a 0–4 rating scale for each number is used in this study. The researcher developed the test independently through selected indicators. So the researcher conducted validity and reliability both non-empirically and empirically. At the non-empirical stage, content validation was carried out by providing a questionnaire containing a scale of 1-5 regarding the research instrument. The data obtained were then entered into the formula that the researcher adopted in the article Lestari et al., (2024) sourced from Widoyoko in 2009. The results are displayed in Table 3. Table 3 displays that the instrument is very good to use according to experts, so a reliability test is carried out using the percentage of agreement. According to Borich in 1994, the percentage of agreement is said to be reliable if it is obtained ≥ 75% (Wicaksono et al., 2020). The test results are shown in Table 4.

Table 3. Content Validation Results

No	Component Aspects	Average		Average	Category
		Expert 1	Expert 2		
1	Substance	5	4,66	4,83	Very good
2	Critical Thinking Skills	5	4,57	4,785	Very good
3	Construction	5	5	5	Very good
4	Language	5	4,75	4,875	Very good
Average				4,8725	Very good

Table 4. Non-Empirical Reliability Results

No	Component Aspects	Average		A-B	A+B	(1-(A-B)/(A+B))	R
		A	B				
1	Substance	5	4,66	0,34	9,66	0,96	96%
2	Critical Thinking Skills	5	4,57	0,43	9,57	0,96	96%
3	Construction	5	5	0	10	1,00	100%
4	Language	5	4,75	0,25	9,75	0,97	97%
Average Percentage							97%

From the reliability test, it can be seen that the instrument is reliable according to experts. Then, an empirical validity test is carried out using a significance test. If the sig. (2 tailed) ≤ 0.05, then the questions used are declared valid. This test involved 46 non-research sample students. Then the valid results are used for further testing on reliability. If the r value (Cronbach's alpha) is more than 0.7, the instrument is said to be reliable; if the r value (Cronbach's alpha) is less than 0.7, the instrument is said to be unreliable (Sajidan et al., 2024). The reliability result was 0.780. This means that the instrument created is suitable for use.

Procedure

Throughout the learning process, the researcher assessed how well the experimental and control groups applied each learning model phase. In the experimental class, the PBL-POE model was used with stages (1) orientation of the problem, (2) organization of the students, (3) prediction, (4) investigation/observation, (5) explanation, (6) analysis and evaluation. Then in the control class, a conventional model was used in the form of Quantum Learning with stages (1) *tumbuhkan*, (2) *alami*, (3) *namai*, (4) *demonstrasikan*, (5) *ulangi*, and (6) *rayakan*. Figures 1 – 4 show several differences in learning models in terms of the stages and some of activity on the worksheet.

The data on the implementation of the learning model was collected using an observation sheet. The observation sheet was filled in by the observer. The data obtained on the observation sheet was then processed using formulas and criteria adopted from Mufidah et al., (2021). This is important to help researchers in the discussion. The learning paradigm was used in both classrooms, and the outcomes fell into the "very good" category.

Figure 1. Discrepant event control class

Figure 2. Discrepant event experimental class

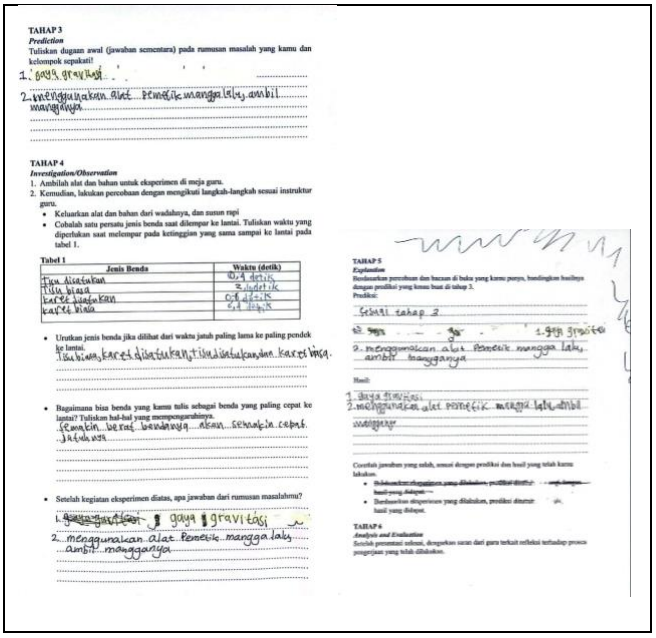

Figure 3. Experimental class activity sheet

Figure 4. Control class activity sheet

RESULTS AND DISCUSSION

Results

The results of this study are used to answer questions and research objectives.

Difference Test Before and After Treatment in Experimental Class

A paired test is used in this difference test. Normality is a requirement for the exam. Table 5 shows that both the pretest and posttest had significance values greater than 0.05. A matched test is then conducted when the data is deemed normal. It yields a value <0.05 in Table 6's sig. value (2-tailed). This indicates that the critical thinking skills of the students in the experimental class differed before and after the PBL-POE paradigm was implemented in science instruction.

Table 5. Experimental Class Normality Test

Group	Significance Value
Pretest Experiment	0,085
Posttest Experiment	0,253

Table 6. Experimental Class Paired Test

Test	Significance Value
Paired Sample T-test	0,000

Difference Test Before and After Treatment in Control Class

A paired test is used in this difference test. Normality is a requirement for the exam. Table 7 shows that both the pretest and posttest had significance values greater than 0.05. A matched test is then conducted when the data is deemed normal. It yields a value < 0.05 in Table 8's sig. value (2-tailed). This indicates that the critical thinking skills of the students before and after the implementation of the conventional model quantum learning in scientific instruction in the control group differ.

Table 7. Control Class Normality Test

Group	Significance Value
Control Pretest	0,114
Posttest Control	0,067

Table 8. Paired Test of Control Class

Test	Significance Value
Paired Sample T-test	0,000

Effectiveness Test

The difference test was followed by the effectiveness test. A non-paired test (independent sample t test) is used in this difference test. Normality and homogeneity are conditions for the test. Table 9 shows that both classes' posttest significance values are > 0.05, indicating normality. This also happens in Table 10, where the data is homogenous with a significance value of 0.446 > 0.05. The independent sample test is then conducted if the data is deemed normal and homogenous. It yields a value <0.05 in Table 11's sig. value (2-tailed). This indicates a difference in the critical thinking skills of students following the implementation of the PBL-POE and conventional approaches in scientific education.

Since the experimental and control groups differ, an effectiveness test is conducted. This is to assess the PBL-POE model's effectiveness. The information required for the Cohen's d effect size test is in Table 12. The test is displayed in Table 13. Table 13 shows that the Cohen's d effect size test results are > 0.8, placing them in the big category. In terms of critical thinking skills this indicates that the PBL-POE model has outperformed the conventional paradigm, namely Quantum Learning. One may also argue that the PBL-POE model outperforms the conventional approach, Quantum Learning, in terms of fostering critical thinking skills.

Table 9. Posttest Normality Test of Control Experiment

Group	Significance Value
Posttest Experiment	0,253
Posttest Control	0,067

Table 10. Homogeneity Test

Test	Significance Value
Homogeneity	0,446

Table 11. Independent Samples Test

Test	Significance Value
Independent Sample T-test	0,000

Table 12. Descriptive Analysis

	group	N	Mean	Std. Deviation	Std. Error Mean
second posttest score of class	1	26	19.73	2.662	.522
	2	26	16.69	2.853	.560

Table 13. Effectiveness Test Results

Test	Cohen's d effect size Value
Cohen's d effect size	1,105

Discussion

This study aims to ascertain its effectiveness of the PBL-POE model on the critical thinking skills of elementary school students. The study's findings demonstrated the effectiveness of the PBL-POE model for critical thinking skills. Furthermore, the answers to research questions 1 and 2 revealed differences before and after learning in both the control and experimental groups. This is understandable, as both models promote student-centered learning. This shows that these two models are worthy of being compared. In addition, several studies have also explained the good impact of the PBL-POE model (Fitriani et al., 2020a, 2020b; Perdanasari et al., 2022). This also happens in the Quantum Learning model (DS et al., 2020; Katmini et al., 2025; Nurjannah & Arifin, 2023). However, articles discussing the PBL-POE model using a quasi-experimental design research type with conventional classes (Quantum Learning) are still difficult to find. Therefore, the results of this research need to be discussed further, namely the PBL-POE model is effective for critical thinking skills.

The effectiveness of PBL-POE is also reflected in the average posttest scores. In the experimental class 70% and the control 60%. The large percentage of the experimental class posttest results compared to the control further supports the 10% difference between the two classes. In general, the experimental class's indicators are higher than the control class's. However, in the based for a decision indicator, the control class experienced a higher average percentage than the experiment. This may suggest that the Quantum Learning model is better at fostering critical thinking skills based on this indicator. However, the rise in the percentage displayed when comparing the results of the pretest and posttest, the PBL-POE model is better than Quantum Learning.

The high level of effectiveness of the PBL-POE model on critical thinking skills is also supported by the learning theory and learning activities in it. In several constructivist theories, learning that uses the PBL-POE model can fulfill everything. In fact, to ensure the success of science learning, constructivism places a strong emphasis on students who build their knowledge through experience (Lestari et al., 2023). The first theory discussed was Vygotsky's constructivism. Vygotsky's theory is known as the Zone of Proximal Development (ZPD). ZPD in this study is a learning objective that adjusts the indicators of critical thinking skills. This research succeeded in bringing students' ZPD to actual development, both in the classroom with PBL-POE learning and Quantum Learning with the same actual development in both classes. This happens because this class has learning objectives that are adjusted to the indicators of students' critical thinking skills. The PBL-POE model also engages students to solve problems. It is also appropriate according to Vygotsky that learning is the result of group problem-solving and is best supported by the use of thorough and authentic activities (Harland, 2003). Problem solving in groups supports the strategy and tactics indicators in this study.

The PBL-POE model also involves social interaction between students in their learning. According to Vygotsky in Hockenbury in 2011, social interaction has a significant impact on cognitive development (Babakr et al., 2019). In addition to social interaction between students, this theory also involves the help of teachers or more experienced peers. In this study, teachers play the role of givers of experience, which is gradually eliminated when students are starting to become proficient. For example, in stage 1 of the PBL-POE model syntax, the teacher at the first meeting guides the stage from the beginning to the end. Then at the last meeting, the teacher has reduced his assistance such that students must be able to do the stage themselves. In this study, teacher assistance according to Vygotsky's theory was not emphasized too much in the Quantum Learning class than PBL-POE.

The second theory discussed is Piaget's constructivism. This theory explains the developmental process and cognitive process in students. In cognitive development, according to Piaget, children aged 10-11 years enter the concrete operational stage. This stage is often known for involving objects that help concretize the student's knowledge in learning. Concrete objects that help this research are objects related to force materials. Learning by involving real or concrete objects is one of the principles of active learning according to Piaget (Pardjono, 2016). The concrete object in this research is presented through experiments. The teacher in this class gives an example of an experiment, before the students do the experiment. The core of teaching and learning in science classes is experimental science and hands-on practice (Moore et al., 2020). This use of experimentation is important because, according to

Piaget in Ornstein in 2011, teachers should encourage students to explore and experiment (Herianto et al., 2024). In addition, the use of experiments accompanied by group activities is very important, because one of the factors in cognitive development is experience with the social environment (Schunk, 2012). This also occurs in classes with the Quantum Learning model. The exchange of ideas in this group learning also supports the improvement of critical thinking skills (Zubaidah et al., 2018).

Then in the theory of cognitive processes, several things are explained, namely schema, assimilation, and accommodation to achieve balance or equilibrium. Equilibrium is one of the factors in cognitive growth according to Piaget (Schunk, 2012). The scheme in this study is that children are able to explain each force concept. The researcher found out that most of the students had answered correctly questions related to this matter that had been given by the teacher. Most students answered correctly when explaining each of the force concepts. It is also part of the actual development that students have according to Vygotsky's theory before receiving treatment.

The second process is assimilation. Assimilation in this study is by providing a cognitive problem. Cognitive problems in the PBL-POE model are created starting when students analyze/identify problem ideas, while experimenting, etc. Meanwhile, in Quantum learning, it starts when student representatives conduct experiments guided by the teacher using two different objects. These things certainly lead to problem solving. In addition, problem-solving must be possible because an 8 year old child according to Lightfoot, Cole, & Cole has already started to solve a problem (Babakr et al., 2019). Meanwhile, the children in this study were 10-11 years old. In the process of assimilation, students learn that each concept of force has a different impact in a certain situation. This is reflected in Figure 1 and Figure 2.

Then, the last process before reaching equilibrium is accommodation. Students are asked to relate the problem of assimilation with other concepts that they understand. Accommodation in the PBL-POE model occurs in stage 5. In this accommodation, students are actively involved in questions and answers with the teacher about the deeper reasons for the answers to the problem formulation after conducting experiments. Based on Figure 3 on the last question in stage 4 and the results in stage 5 regarding the answer to the second problem formulation, students answered orally in groups why they chose the answer because the mango picking tool does not waste energy and is more efficient. The student explained that using only stones could be risky and that maximum energy use would be at the beginning because it would eventually run out due to fatigue. This signified that students understood the relationship between force and energy. This demonstrated that the students' accommodation requirements were met. The teacher then continued to probe students until they found the answer: the energy comes from chemical energy obtained through food. From this, the equilibrium has been met because students are able to relate it to more complex things. Teacher questions and answers about cause and effect are one way to stimulate critical thinking skills, because it stimulates students' minds (Orlich et al., 2010).

If viewed from Piaget's constructivism theory, the underlying factor in the effectiveness of the PBL-POE model is the occurrence of accommodation in the model while in Quantum Learning such experience does not occur. This is important because the balance of cognitive processes will not be achieved. Balance itself is the most important factor in cognitive development according to Piaget (Schunk, 2012). This study employs the identical scheme for the control and experimental classes. So the Quantum Learning model cannot be underestimated because there are several things that happen that have similar values to PBL-POE and vice versa. Learning with Quantum Learning lacks support for the accommodation process for students. As a result, students are unable to achieve equilibrium, unlike learning that uses the PBL-POE model.

In addition, another proof that equilibrium has been achieved is the coordinated action of the other three factors of Piaget's cognitive development, of which equilibrium is the main factor (Schunk, 2012). Those three factors are experience with the physical world, experience with the social environment, and biological maturity (Schunk, 2012). The experience of the physical world occurs when students experiment with using media such as in Figure 1 and Figure 2. Then the experience of the social environment occurs when students work together with their group from start to finish, one of which is when experimenting as Figure 2. Finally, students already have biological maturity in solving problems because they are 10-11 years old. The 8 year old son according to Lightfoot, Cole, & Cole has already started to solve a problem (Babakr et al., 2019). This already reflects the biological maturity of students.

The last learning theory that supports the results of this study is information processing. This theory is important because it is closely related to the problem-solving process in students (Nur et al., 2024). Because to produce a workable solution, a deep understanding of the problem is required, and decision making requires adequate information and critical thinking (Yu et al., 2020). Information processing theory is a cognitive theory of learning that describes the processing, storage, and retrieval of knowledge in the mind (Slavin, 2006). This depiction starts from the sensory register, short term memory, and long term memory.

If viewed from attention to sensory register and to shorter memory in information processing theory, it is true that the Quantum Learning model is better. As seen in Figures 1, the attention given results in discrepant events in the second stage of the Quantum Learning model. This will certainly cause cognitive conflict and have an impact on students' critical thinking skills (Ramadhani & Ayriza, 2019). In addition, the Quantum Learning model in its stages also facilitates the occurrence of sensory registers earlier when compared to the PBL-POE model. This happens because the Quantum Learning stage is in the second stage. While PBL-POE in stage 4 occurs the sensory register process. Sensory registers in this research are closely related to experiments. The application of this experiment is important because, according to Piaget in Ornstein in 2011, teachers must encourage students to explore and experiment (Herianto et al., 2024). The presence of both processes in each experimental and control group allows the process towards long-term memory to occur.

In the process of long term memory, this research leads to the type of semantic memory. Semantic memory discusses facts, general information, concepts, principles, problem-solving skills and learning strategies (Slavin, 2006). In semantic memory, information is obtained in the form of a network of ideas (Slavin, 2006). Such a network of interconnected ideas or relationships is called schema (Slavin, 2006). The scheme was also introduced by Piaget and this process allows one to understand and enter new information. The processing forms a lot of ideas, which in this PBL-POE model is facilitated in the activity sheet (in Figure 3). The activity sheet in this study allows students to access all information, especially in stage 4. If seen from the student worksheet of the control class in Figure 4, the activity is indeed less directing students towards long-term memory, because the things they want to find out are few.

In one of the student worksheet meetings in the control class, students were more directed to be critical, while most of the other meetings were only related to determining/differentiating things that happened including what type of style. This is certainly different from the PBL-POE model where each meeting facilitates students for their capacity for critical thinking skills. However, it ought to be mentioned here, the main focus is still the learning model, not the student worksheet. The student worksheet in the PBL-POE model is indeed more coherent because starting from the first stage it requires students to read the discourse. Where this can be facilitated by the student worksheet. This is part of the design of the learning model that places students as active subjects in the critical thinking process. Therefore, the main focus remains on the learning model, not merely on the student worksheet as a supporting tool.

According to Solso in 2001, the amount of access to obtain information is good for the long term memory process (Slavin, 2006). Because the main problem with the long term memory process is the loss of access to information, not the loss of information (Slavin, 2006). So information processing theory has an important role, because learning will be remembered by students for a long time. In addition to being supported by previous research and the theory of learning the birth of models, this research is also supported by the emergence of critical thinking skills activities at the PBL-POE model stage. This is what makes the PBL-POE model more effective in this science learning.

The PBL-POE model is indeed better, but some principles do not originate from that model. The Quantum Learning model has principles in multiple intelligences (Acat & Ay, 2014), while PBPOE does not. However, this did not have much effect on this study because the control class teacher did not carry out the educational process according to the intelligence of the students. This also happened in the experimental class, because if you want to carry out learning based on student intelligence in the PBL-POE model, it is also possible.

Both learning models have also been implemented “very good” based on the findings of observations made by observers. Because, if the syntax isn't implemented properly, it's tantamount to failed learning. This will certainly impact the achievement of the desired goals. This is also supported by research conducted by Fadilla et al., (2021), which shows that the implementation of the PBL model

can improve students' critical thinking skills, provided that both teachers and students follow each step of the PBL syntax properly. However, the similarity of some of these things does not change that the results show that PBL-POE is more effective with a greater impact when compared to Quantum learning on critical thinking skills. This is important because it has witnessed extraordinary and rapid changes, both in technology and culture since the turn of the 21st century (Care et al., 2024). Undoubtedly, this shift has a significant effect on the education industry, especially on the process of learning (Kusumaningtyas, Utama, et al., 2025). Students need to acquire 21st century skills, both now and in the future (Benek & Akcay, 2022). Thus, the PBL-POE paradigm may be applied as a substitute for traditional learning methods.

Testing the effectiveness of the PBL-POE model has also been carried out on several variables by its developers (Fitriani, 2020). Effectiveness is only measured through a difference test in the form of Anacova then tested LSD (Fitriani, 2020). The Cohen's d effect size test was employed to ascertain the degree of the effectiveness in this study after the Independent Sample T-test. This is certainly a differentiator and advantage in this study. Because in some studies, effectiveness is only carried out until the difference test by comparing group 1 with others (Lubis et al., 2022; Moreno-Palma et al., 2024; Wati et al., 2024). The effectiveness of the PBL-POE model is indeed proven. However, if implemented in continuous learning, it presents several challenges. This model requires considerable preparation and implementation time. The use of the PBL-POE model is best for students who have mastered basic cognitive levels such as C1-C2, but have problems at higher levels such as critical thinking. Conceptual understanding still needs to be taught well to elementary school students, rather than having to force critical thinking on a material.

CONCLUSION

This study successfully achieved its objective: to determine the effectiveness of the PBL-POE model on the critical thinking skills of elementary school students. The PBL-POE model proved more effective than the conventional Quantum Learning model in developing critical thinking skills. Based on the research questions, it was found that there were differences before and after using the learning model, both in the experimental and control groups. Teachers can utilize this model to foster critical thinking skills in elementary schools. Therefore, the PBL-POE model should also be tested on other variables such as science process skills, etc.

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