25 (4), 2024, 1961-1975
Jurnal Pendidikan MIPA
e-ISSN: 2685-5488 | p-ISSN: 1411-2531
http://jurnal.fkip.unila.ac.id/index.php/jpmipa/

The Effect of the PODE Learning Model Assisted by Digital Pop-Up Books on Science Conceptual Understanding and Critical Thinking Skills of Elementary Students

Inayatul Muntaqiyah[1], Singgih Bektiarso[2,*], & Rizki Putri Wardani[1]
[1]Departement of Elementary School Teacher Education, Universitas Jember, Indonesia
[2]Departement of Physics Education, Universitas Jember, Indonesia

Abstract: One of the fundamental skills in science learning is concept understanding and critical thinking. However, science learning in schools has not focused on developing these two abilities. The purpose of this research is to examine the effect of the PODE learning model assisted by a digital pop-up book on the understanding of science concepts and critical thinking skills of elementary school students. The method applied in this study is experimental with a quasi-experimental design through a post-test-only non-equivalent control group approach. Based on the data analysis, it was found that PODE learning assisted by digital pop-up book media has a significant effect on concept understanding and critical thinking skills. Multivariate analysis showed a significant difference simultaneously on both dependent variables with a significance value of 0.000. Referring to the data obtained in this study, researchers suggest using the PODE model assisted by digital pop-up book media to improve students' understanding of science concepts and critical thinking skills. For future researchers, it is recommended to conduct longitudinal research on the PODE model and digital pop-up book media, as well as examine its effect on other variables such as creative thinking skills, higher-order thinking skills (HOTS), science process skills, and others.

Keywords: PODE learning model, digital pop-up book, science concept understanding, critical thinking skills, elementary school students.

▪ INTRODUCTION

Human resources that are skilled and can adapt to the demands of globalization can be developed through education. The current global era requires education to produce young people who can think critically and understand deep scientific concepts (Cynthia & Sihotang, 2023). Students must develop important basic skills early on, especially concept understanding and critical thinking (Khofiyah and Santoso 2019). Concept understanding and critical thinking skills are fundamental skills in learning science. Conditions in the field show that the Indonesian education sector has not been able to facilitate the development of these two abilities thoroughly. Learning in elementary schools is still dominated by conventional teacher-centered approaches that seem monotonous (Hadi and Kasum, 2015). As a result, students often have difficulty understanding the material and lack critical thinking skills.

Concept understanding and critical thinking skills play an important role in measuring the success of innovative learning. Concept understanding is the level of mastery of the material by students according to learning objectives, which includes the ability to understand concepts that have been known or remembered as a higher form of thinking than mere memorization so that with good concept mastery, students can increase knowledge and problem-solving skills with teacher guidance (Putra et al., 2018; Suryani, 2019; Wardani, 2019). Anderson and Krathwohl (2010) stated that indicators of concept understanding include interpreting, giving examples, classifying, summarizing,

Inayatul Muntaqiyah
*Email: Inayatul050103@gmail.com

DOI: http://dx.doi.org/10.23960/jpmipa/v25i4.pp1961-1975
Received: 13 January 2025
Accepted: 23 January 2025
Published: 28 January 2025

drawing inferences, comparing, and explaining. Concept understanding has a close relationship with critical thinking skills. Critical thinking skills are defined as the ability to analyze, evaluate information, and make logical decisions that can be accounted for (Martika 2017; Suciono 2021). According to Facione and Gittens (2016), critical thinking indicators include interpretation, analysis, inference, evaluation, explanation, and self-regulation. With critical thinking skills, students are expected to be able to improve the quality of their reasoning by monitoring and evaluating the thinking process and its results.

A common challenge among students is their limited understanding of abstract concepts in science that cannot be observed directly (Dinatha, 2017). In fact, with good mastery of concepts, students can increase their knowledge in solving problems through direct involvement in understanding concepts with teacher guidance (Wardani, 2019). In addition, many students have difficulty in answering questions that require analysis and problem-solving. This condition indicates the low level of understanding of science concepts and critical thinking of students. Learning in elementary schools is still dominated by conventional teacher-centered learning that seems boring (Hadi & Kasum, 2015). Thus, students often face difficulties in understanding the material and lack critical thinking. As a result, students find it difficult to apply science knowledge in everyday life (Nahdi et al., 2018).

One solution to these challenges is using the PODE (Predict-Observe-Discuss-Explain) learning model. The PODE model is a development of the POE (Predict-Observe-Explain) learning model introduced by White and Gunstone in 1995 in their book entitled Probing Understanding (Irfan, 2017). The main development innovation in this model is the addition of discussion syntax that allows students to conduct collaborative learning (Syamsuadi, 2017). Syamsuadi (2017) further states that the PODE model consists of four learning stages, namely Predict (predicting phenomena), Observe (directly observing), Discuss (discussing findings), and Explain (explaining results and comparing them with predictions). The learning theory underlying the PODE learning model is Piaget's constructivism theory. According to Piaget, primary-level students are in the concrete operational phase. At this stage, students do not just absorb material from the teacher but students act as active learners who build their own understanding (Marinda, 2020; Muna, 2017). Students integrate various information from their learning environment with their existing knowledge to form a new comprehensive understanding (Wiguna, 2018).

The PODE learning model has a strong relevance to the characteristics of science learning. In science learning, students are required to understand scientific concepts and develop their critical thinking skills through direct involvement in the scientific discovery process (Avandra, 2022). Through systematic learning stages, the PODE learning model can facilitate these needs. Learning begins with the prediction stage, which encourages students to make initial guesses using scientific reasoning based on their prior knowledge (Mubarok et al., 2020). Followed by the second stage of observation, where students make direct observations about a scientific phenomenon. When observing a phenomenon, students are able to improve their science process skills such as observing, measuring, and recording data (Hasibuan et al., 2023). The third stage is a discussion that helps students improve their concept understanding and critical thinking skills through social interaction. In this discussion, students can compare the results of predictions with the observations they get (Syamsuadi, 2017). The last stage is explanation, students are required to provide scientific explanations of phenomena based on the evidence obtained at the observation stage. At the explanation stage, students are able to construct their understanding according to the results of observations with relevant science concepts so that they can make logical conclusions (Kartikasari, 2022). Thus, the four stages in the PODE model can improve students' understanding of science concepts and critical thinking skills.

The PODE learning model contributes to a deeper understanding of science concepts by involving students in active knowledge building. When students into the prediction stage, they naturally draw upon their eisting knowledge base and sreating meaningful connections with scientific concepts (Fatimatuzzohrah et al., 2020). Through direct observation, students have the opportunity to validate the truth of the predictions they have made before (Muna, 2017). Group discussions facilitate the exchange of ideas and clarification of concepts within the group (Faizah et al., 2021). Then the explanation stage allows students to integrate their prior knowledge with the new knowledge they get (Syamsuadi, 2017).

In developing critical thinking skills, each stage of the PODE learning model contributes to training various aspects of students' critical thinking in science learning. In the prediction stage, students develop inference skills to predict what will happen in a scientific phenomenon presented (Fadiah, n.d.). The observation stage trains analysis and interpretation skills to identify, observe, and collect data (Ariq & Fitrihidajati, 2021). The discussion stage hones the ability of evaluation and self-regulation to assess the credibility of their own observations and the statements of their peers (Widiastuti & Kania, 2021). While the explanation stage encourages students to synthesize learning by building logical scientific explanations and basing them on empirical evidence (Syamsuadi, 2017).

The effectiveness of the PODE learning model can be improved through its integration with innovative learning media, especially digital pop-up books. Research conducted Huda (2020) and Maritsa et al. (2021) revealed that the use of technological media can significantly improve the quality of learning and knowledge transfer. Digital pop-up book media can transform abstract science concepts into interesting and interactive visual representations that can facilitate deeper student understanding. The lack of learning facilities in schools is one aspect that results in limited students' critical thinking skills (Damayanti., Bektiarso., dan Maryani, 2022). In line with this, Rahmayanti and Setiawan (2023) revealed that digital pop-up books were indicated to improve students' critical thinking skills. Digital pop-up books combine the advantages of traditional pop-up books with advances in digital technology, which offer features such as moving animations, sound effects, and easy accessibility.

Preliminary observations conducted by researchers at SDS NU 17 Baitul Makmur indicated that science learning in grade 4 currently uses a cooperative learning model with learning media limited to textbooks and simple props. Although this model is quite effective, there are still opportunities to improve students' understanding of science concepts and critical thinking skills, especially in connecting theory with practical real-world applications.

Several previous studies have shown positive results in the application of the PODE model and digital pop-up books in education. Herdianto et al., (2022) found that integrating practical activities in the PODE model improved understanding of science concepts among elementary school students. Ramadhanti (2022) corroborated this, showing the positive impact of PODE on concept understanding and learning outcomes. In addition, Fauziyah & Mulyani (2024) revealed that digital pop-up books effectively improved students' understanding of the concept of force. Regarding critical thinking skills, Cesariyanti et al. (2022) showed that the implementation of the PODE model with Vlab improved students' critical thinking in physics practice. Similarly, Rahmayanti & Setiawan (2023) proved that digital pop-up books positively influence critical thinking skills in science learning.

Based on some of the research above, it can be seen that the PODE learning model has been proven effective in various learning contexts. However, the implementation of the PODE learning model has limitations in visualizing abstract science concepts for elementary school students. Meanwhile, digital pop-up book media has advantages that can overcome these limitations. Digital pop-up book media can present abstract science concepts in the form of dynamic visualization with interactive features (Mutiara & Hardjono, 2023). However, the integration between the PODE model and digital pop-up book media to improve elementary students' concept understanding and critical thinking skills in science learning has never been systematically studied.

Based on this background, this study seeks to fill the gap by integrating digital pop-up book media into the PODE model to optimize concept understanding and critical thinking skills of elementary school students. This integration is expected to overcome the limitations of the PODE model through more dynamic and interactive visualization while utilizing digital technology in science learning. This research is focused on science class IV Chapter 2 material about the form of substances and their changes. The results of this study are expected to provide practical contributions to the development of science learning in elementary schools.

▪ METHOD

Participant

Research subjects were taken from the entire population of 36 fourth-grade students at SDS NU 17 Baitul Makmur for the 2024/2025 academic year. A homogeneity test was conducted using previous chapter test scores from classes IVA and IVB before sample selection. Using purposive sampling, class IVA (20 students) was selected as the experimental group, and class IVB (16 students) as the control group.

Research Design and Procedures

The methodology applied in this study used a quasi-experimental design with a post-test-only non-equivalent control group pattern. The research design uses two groups, namely an experimental group that is given special treatment and a control group that does not receive special treatment. Both groups were given a post-test after the learning took place (Sugiyono, 2019). The PODE learning model assisted by digital pop-up book media acts as an independent variable, while concept understanding and critical thinking skills act as dependent variables.

The research procedure consists of three stages, namely planning, implementation, and the end. The planning stage includes problem formulation, literature review, school observation, preparation and validation of instruments, preparation of learning media, preparation of teaching modules, and homogeneity tests using previous material test scores. The implementation stage lasts for four meetings in each class, where the time allocation for each meeting is 3x35 minutes. The experimental class applied the PODE learning model with 4 systematic stages: (1) Predict, at this stage, students make initial predictions about the phenomenon of the form of substances and their changes displayed through digital pop-up books, (2) Observe, at this stage, students conduct experiments and direct observations of a phenomenon, (3) Discuss, at this stage, students discuss with groups to compare the results of predictions and observations, and (4) Explain, at this stage, students compile and present the results of their observations and discussions based on real evidence. At this stage, the teacher provides reinforcement, confirms, and straightens out incorrect concepts, and completes the material that has not been conveyed with the help of digital pop-up books. Thus, it is expected that the material can be conveyed thoroughly. The digital pop-up book media was used mainly at the prediction stage to visualize scientific phenomena and at the explained stage to support the teacher's explanation. In addition, the control class used STAD type cooperative learning with a digital pop-up book. After the learning activities are completed, both groups will be given a post-test. In the final stage, the post-test data of students' concept understanding and critical thinking skills were analyzed using inferential statistics to conclude.

Research Instrument

Data collection was done through a post-test using test instruments that understand concepts and critical thinking skills. The concept understanding test instrument was prepared based on Anderson and Krathwohl's (2010) six indicators of concept understanding, namely interpreting, giving examples, classifying, summarizing, drawing inferences, comparing, and explaining. While the critical thinking skills test was prepared based on five indicators of critical thinking Facione & Gittens (2016) namely interpretation, analysis, inference, evaluation, explanation, and self-regulation.

The development of this research instrument was carried out through several stages. At the initial stage, the preparation of the test instrument. To measure concept understanding, 21 items of multiplechoice questions were prepared, where each indicator of concept understanding amounted to 3 questions. The distribution of questions for each indicator of concept understanding is presented in Table 2 below.

Table 2. Conceptual understanding test instrument grid

Concept Understanding Indicators	Question Indicators	Number of Questions
Interpreting	Interpret/understand the process of changing the form of substances.	3
Exemplifying	Give examples of various forms of substances and the phenomenon of changes in the form of substances	3
Classifying	Classify/categorize the properties and changes in the form of substances.	3
Summarizing	Make a summary of the properties and changes in the form of substances.	3
Inferring	Draw inferences/ make conclusions about the properties and changes in the form of substances.	3
Comparing	Compare/contrast various kinds of changes in the form of substances.	3

Explaining	Explain the properties and changes in the form of substances.	3

Meanwhile, to measure critical thinking skills, 6 essay questions were prepared and each question represented one indicator of critical thinking skills. The distribution of questions for each indicator of critical thinking skills is presented in Table 3 below.

Table 2. Critical thinking skills test instrument grid

Critical thinking skills Indicators	Question indicators	Number of questions
Interpretation	Interpret or understand the event of changing the form of a substance.	1
Analysis	Analyze or identify the nature of the form of substances.	1
Inference	Draw inferences/conclusions based on the information presented about changes in the form of substances.	1
Evaluation	Evaluate the correctness of arguments about changes in the form of substances.	1
Explanation	Present reasoning about the event of changes in the form of substances accompanied by scientific reasons.	1
Self-regulation	Correcting errors in thinking about changes in the form of substances.	1

In the next stage, the two test instruments were validated by two expert validators, namely a PGSD lecturer at the University of Jember and a 4th-grade teacher at SDS NU 17 Baitul Makmur using a scale of 1-5. The validation of the questions was carried out based on 3 aspects of the assessment, namely (1) the instructions for working on the questions including clarity and completeness of the instructions, (2) the suitability of the material with the indicators and the cognitive level of the students, and (3) the use of language in the test instrument includes conformity with Indonesian language rules, does not contain double meanings, and uses simple language that is easy for elementary students to understand. The results of the validation of the concept understanding test instrument obtained a product validation value (Valpro) of 85.83 and the critical thinking skills test instrument obtained a Valpro value of 90. Both product validation results are included in the very feasible category based on Masyhud's (2021) categorization.

After expert validation, the research instrument was empirically tested on 25 grade 4 students of MI Al-Husna to determine the validity and reliability of the question items. From the validity test results, 16 valid multiple choice questions were obtained to measure concept understanding, and all critical thinking essay questions totaling 6 questions were declared valid. The reliability test was carried out using the Spearman-Brown formula with the results for the concept understanding instrument obtained a reliability coefficient value (r_{11}) of 0.88 which was included in the high-reliability category, while the critical thinking skills instrument obtained a reliability coefficient value (r_{11}) of 0.73 which was also included in the high-reliability category. The question items that have been declared valid and reliable are then used in research.

Data Analysis

Data analysis in this research used Multivariate Analysis of Variance (MANOVA) to test the hypothesis because it involved two dependent variables, understanding of science concepts and critical thinking skills. Before conducting MANOVA, prerequisite tests were conducted, including the Shapiro-Wilk normality and the variance-covariance matrix homogeneity test using Box's M test. Hypothesis testing used Pillai's Trace statistic at a 5% significance level ($\alpha = 0.05$). The magnitude of the treatment effect was calculated using the Partial Eta Squared (η^2) effect size with the criteria of small (0.01 - 0.05), medium (0.06 - 0.13), and large ($\geq$ 0.14) effects (Cohen, 2013). All data analysis was performed using SPSS version 26.0.

▪ RESULT AND DISSCUSSION

Based on the results of experiments and data collection, data obtained in the form of post-test results of concept understanding and critical thinking skills of students. The next step is descriptive analysis and data analysis with prerequisite test stages in the form of normality tests and homogeneity tests. Next, hypothesis testing was carried out using the MANOVA test.

Descriptive Analysis

The research data were obtained from the post-test results conducted in the experimental group and control group after treatment. The recapitulation of the post-test results is presented in descriptive statistics in Table 4 below.

Table 4. Descriptive statistics of post-test results

Variable	Group	N	Min	Max	Mean	Std. Deviation
Understanding Conceptual	Experiment	20	56	100	80.80	11.861
	Control	16	19	100	64.19	20.961
Critical Thinking Skills	Experiment	20	38	92	71.50	11.954
	Control	16	17	67	49.25	13.694

The difference in post-test results between the experimental and control groups can be visualized through Figure 1 below.

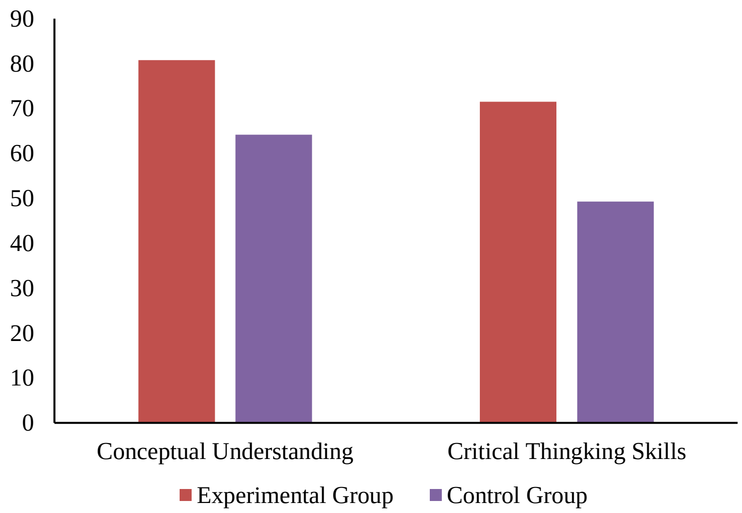

Figure 1. Comparison of post-test results

Based on Table 4 and Figure 1 above, it can be seen that the experimental class obtained higher post-test results than the control class, both on the concept understanding test and the critical thinking ability test. In concept understanding, the experimental class obtained an average score of 80.80 (SD = 11.861), while the control class only obtained an average of 64.19 (SD = 20.961), which showed a difference of 16.67 points. Meanwhile, in critical thinking skills, the experimental class obtained an average of 71.50 (SD = 11.954) and the control class obtained an average of 49.25 (SD = 13.694), with a difference of 22.25 points. This shows that the experimental class obtained higher post-test results than the control class on both variables.

Prerequisite Tests

Before conducting MANOVA analysis, prerequisite tests were first performed in the form of normality and homogeneity tests. The Shapiro-Wilk normality test results showed normally distributed data (p > 0.05) as presented in Table 5 below.

Table 5. Shapiro-wilk normality test result

Tests of Normality							
		Kolmogorov-Smirnova			Shapiro-Wilk		
	Class	Statistic	df	Sig.	Statistic	df	Sig.
CU	Experiment Class	.178	20	.096	.950	20	**.374**
	Control Class	.161	16	.200*	.975	16	**.907**
CTS	Experiment Class	.173	20	.120	.918	20	**.089**
	Control Class	.198	16	.093	.896	16	**.068**

**. This is a lower bound of the true significance.*
a. Lilliefors Significance Correction

Furthermore, the homogeneity test was carried out using Box's M test which resulted in a significance value of 0.091 (sig ≥ 0.05) indicating the existence of homogeneity of variance-covariance between experimental and control classes, as shown in Table 6 below. Thus, the prerequisites for MANOVA testing were met.

Table 6. Box's M test result

Box's Test of Equality of Covariance Matrices[a]	
Box's M	6.914
F	2.155
df1	3
df2	268309.116
Sig.	**.091**

Tests the null hypothesis that the observed covariance matrices of the dependent variables are equal across groups.
a. Design: Intercept + Group

Hypothesis Testing

After the normality test and homogeneity test are carried out, hypothesis testing will then be carried out. This study tests the hypothesis using the MANOVA test as presented in Table 7. below.

Table 4. MANOVA test result

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Intercept	Pillai's Trace	.968	502.776b	2.000	33.000	.000	.968
	Wilks' Lambda	.032	502.776b	2.000	33.000	.000	.968
	Hotelling's Trace	30.471	502.776b	2.000	33.000	.000	.968
	Roy's Largest Root	30.471	502.776b	2.000	33.000	.000	.968
Class	Pillai's Trace	.449	13.463b	2.000	33.000	.000	**.449**
	Wilks' Lambda	.551	13.463b	2.000	33.000	.000	.449
	Hotelling's Trace	.816	13.463b	2.000	33.000	.000	.449
	Roy's Largest Root	.816	13.463b	2.000	33.000	.000	.449

a. Design: Intercept + Group

b. Exact statistic

Based on the multivariate test table, in the "class" row, Pillai's Trace statistic shows Sig. 0,000 < 0,05. This means that H0 is rejected and Ha is accepted. Thus, there is a significant difference in concept understanding and critical thinking skills simultaneously between students who follow PODE learning assisted by digital pop-up book media and students who follow STAD cooperative learning assisted by digital pop-up book media.

Discussion

Concept understanding and critical thinking skills are closely related in the learning process, especially in science learning. According to Berns and Erickson (Alatas, 2014), understanding concepts can be considered as a foundation for acquiring problem-solving skills, creative and critical thinking, and decision-making skills. The level of understanding of student concepts is directly proportional to their critical thinking skills. The better students understand the concept, the higher their critical thinking ability. Conversely, low concept understanding tends to produce low critical thinking skills(Nugraha et al., 2022; Prasetyowati & Suyatno, 2016). In line with that, Rochmad et al., (2018) stated that to have critical thinking skills in problem-solving, it is necessary to understand the concepts related to the problem at hand

Based on this opinion, it can be concluded that a good understanding of concepts can improve students' critical thinking skills, and vice versa. Students who have a good understanding of concepts will find it easier to analyze information more deeply, develop their understanding more logically, and apply their knowledge. In addition, critical thinking skills can help students expand their understanding of a concept. Digital pop-up book media can strengthen the relationship between concept understanding and critical thinking skills through its interactive features and dynamic visualization. When students use digital pop-up books, they do not only receive information passively but students can be actively involved in in-depth analysis. The visualization of materials in the form of interactive animations and interestingly packaged information allows students to see the form of substances and their changes dynamically. Thus, this media can to help students connect abstract concepts in science with concrete phenomena. The implementation of this technology-integrated learning model results in a simultaneous increase in conceptual understanding and hones students' critical thinking skills. This finding is proven by the results of a study that examined the effect of the PODE model assisted by digital pop-up book media on students' conceptual understanding and critical thinking skills. Statistical analysis using the MANOVA test, resulted in a significance value of $0.000 < 0.05$, indicating a statistically significant difference in student's conceptual understanding and critical thinking skills after a simultaneous intervention.

The results showed that there was a significant influence between the PODE model assisted by digital pop-up book media on students' concept understanding. These results are in line with David Ausubel's meaningful learning theory, which states that meaningful learning occurs when students successfully integrate existing knowledge with new information (Lay et al., 2024). This is in accordance with the PODE model which facilitates student learning activities through systematic and structured stages to improve student understanding. The application of Ausubel's meaningful learning theory in this study is realized when students actively connect their prior knowledge about the form of substances and their changes with new experiences through prediction, observation, discussion, and explanation activities. In addition, students integrate their initial understanding of the form of substances and their changes with new experiences through digital pop-up books. For example, when students have prior knowledge about the change in the form of water-to-water vapor, this digital pop-up book helps students understand the phenomenon through dynamic visualization. This allows the assimilation of new knowledge into existing cognitive structures.

This finding is also supported by Jerome Bruner's discovery learning theory. According to Bruner in Lastini et al., (2024), learning becomes effective if it goes through three stages, namely enactive (action), iconic (visual), and symbolic (language). PODE model learning assisted by digital pop-up book media combines the three stages of learning. The PODE learning process is in line with the principles of Bruner's learning theory which states that learning should encourage students to actively discover knowledge to produce a deep and meaningful understanding (Inayati, 2022). Bruner's three stages of learning are comprehensively realized in this study. The enactive stage occurs when students conduct direct experiments on changes in the form of substances. The iconic stage is strengthened through the visualization of digital pop-up book media that presents animated examples and phenomena of changes in the form of substances. The symbolic stage is realized when students can demonstrate conceptual mastery through presentation and use their language in the explained stage. The development of these skills is evident from the students' increased understanding of the concept of the form of substances and their changes.

Research on the effect of the PODE model assisted by digital pop-up book media Research on the effect of the PODE model assisted by digital pop-up book media on critical thinking skills is based on Jean Piaget's constructivism learning theory. Piaget's developmental theory places elementary school-age children (7-11 years) in the concrete operational stage (Marinda, 2020). At this stage, children begin to have logical reasoning about concrete phenomena. By the characteristics of these elementary school students, the PODE model assisted by digital pop-up book media helps students build their knowledge through direct involvement in learning. The PODE learning model encourages the assimilation and accommodation of students' knowledge, while the digital pop-up book media provides concrete visual representations. Piaget's theory of constructivism emphasizes that children actively construct knowledge through interaction with their environment (Hendrowati, 2015; Nurhidayati, 2017). This is in line with the characteristics of the PODE model which encourages active involvement of students in the learning process. The results showed that this constructivist approach was effective in improving students' critical thinking skills.

Systematically, the PODE model encourages the development of students' critical thinking skills. This is supported by research by Cesariyanti et al., (2022) which reveals that the PODE model can improve critical thinking skills. In the prediction stage, students predict the material state of an object and the possible changes that will occur in experimental activities. This requires students' interpretation skills to analyze answers according to prior knowledge. At the observation stage, honing analysis and inference skills where students conduct experiments directly. Then during group discussions, students need evaluation skills to assess the opinions or arguments of peers and compare their findings during experiments. At the explanation stage, students make presentations and compare them with their initial predictions. At this stage, students can reflectively organize their thought processes independently, question initial predictions, and integrate them with new information based on concrete evidence (Syamsuadi, 2017) .

In this study, digital pop-up book media acts as an effective learning media to improve students' conceptual understanding and critical thinking skills. This is supported by the research of Kusumawati et al., (2024) and Susilawati et al., (2025) which showed a significant impact of digital pop-up books in improving concept understanding and critical thinking skills. This media is designed to support students' cognitive development in understanding learning materials about the concept of substance form and its changes. During the 4 meetings in the research activities in the experimental class, this media was implemented in the explained syntax to strengthen and expand students' understanding of the form of substances and their changes. The advantage of this media lies in the ability to visualize abstract concepts into concrete representations that are easily understood by elementary school students (Islami et al., 2024). Through information, animation, and attractive displays, this media effectively overcomes students' difficulties in understanding abstract science concepts (Masrifa et al., 2023). Visualization of concepts through this media not only facilitates students in understanding concepts but also encourages students to actively explore, question, and build in-depth knowledge. This is evidence of the positive contribution of digital pop-up book media in improving students' concept understanding and critical thinking skills.

Although this study shows positive results, some limitations need to be considered. First, the effectiveness of using learning media is highly dependent on the availability and quality of technological infrastructure in schools. Second, the relatively short duration of the study limits the results to the long-term impact of using the PODE model and digital pop-up book media. Third, the learning styles and characteristics of each student may not all be suitable for digital-based learning. Fourth, environmental factors such as parental support and differences in socio-economic conditions may affect the effectiveness of learning implementation. Finally, this study has not measured other aspects that may be affected such as students' learning motivation and collaborative ability. These limitations need to be considered when applying the PODE model assisted by digital pop-up book media in different contexts.

The practical implications of these findings suggest that educational institutions should prioritize adequate technological infrastructure to facilitate effective learning processes. The use of appropriate technological devices can significantly improve the quality of learning and student success in learning (Huda, 2020). Based on the results of this study, which showed a positive impact of the PODE learning model assisted by digital pop-up book media on concept understanding and critical thinking skills, teachers should consider adopting this model and media in science materials or other disciplines. This study provides an opportunity for further research on the PODE model and digital pop-up book media, especially to see its effect in the long term and see its potential effect on other cognitive abilities such as creative thinking skills, higher order thinking skills, science process skills, and others

▪ CONCLUSION

Based on the research that has been conducted, it can be concluded that the PODE (Predict-Observe-Discuss-Explain) model assisted by digital pop-up book media provides a significant impact on the understanding of science concepts and critical thinking skills of students simultaneously. MANOVA analysis results show a significance value of 0.000 ($p < 0.05$), which indicates the effectiveness of this learning. The post-test results showed the average concept understanding score in the experimental group was 80.80 while the control group was 64.19, while for critical thinking skills, the experimental group obtained an average of 71.50 and the control group was 49.25. The experimental group using the PODE learning model assisted by digital pop-up book media showed higher results in concept understanding and critical thinking skills compared to the control group. This finding confirms the importance of using interactive learning models that integrate with digital technology in science learning at the elementary school level to improve the quality of learning.

The implication of this study is to emphasize the importance of technological infrastructure support in schools and improving teachers' competence in designing learning using appropriate learning models and integrating them with digital technology. Some limitations that need to be considered in this study are the dependence on technological infrastructure in schools, the relatively short duration of the study, differences in student’s learning styles, environmental factors such as parental support and students' socio-economic conditions, and the unmeasured other aspects of learning such as learning motivation and collaborative skills. These limitations need to be taken into consideration in the application of similar learning models and media in different contexts and can be the basis for further research.

▪ REFERENCES

Alatas, F. (2014). *Hubungan pemahaman konsep dengan keterampilan berpikir kritis melalui model pembelajaran treffinger pada mata kuliah fisika dasar.*

Anderson, L. & K. D. . (2010). *Kerangka landasan untuk pembelajaran, pengajaran, dan asesmen. Pustaka pelajar.*

Ariq, M. I., & Fitrihidajati, H. (2021). *Validitas E-LKPD "ekosistem" berbasis saintifik untuk melatih keterampilan berpikir kritis siswa kelas X SMA.* Berkala Ilmiah Pendidikan Biologi (BioEdu), 10(3), 562–571.

Avandra, R. (2022). *Implementasi pembelajaran berdiferensiasi terhadap keterampilan berpikir kritis siswa pada pembelajaran ipa kelas vi sd.* Didaktik: Jurnal Ilmiah PGSD STKIP Subang, 8(2), 2944–2960.

Cesariyanti, Y., Hasanah, A. R., Fitriani, A. N., Malik, A., Nurhayati, A., Putra, R. P., Agustina, R. D., Studi, P., Fisika, P., Putra, R. P., & Agustina, R. D. (2022). Critical thinking · magnetic field PODE Model VLab. Scientific Research, 7(1), 43–50. https://ejournal.upi.edu/index.php/WapFi/article/view/42503

Cohen, J. (2013). Statistical power analysis for the behavioral sciences. routledge.

Cynthia, R. E., & Sihotang, H. (2023). *Melangkah bersama di era digital: pentingnya literasi digital untuk meningkatkan kemampuan berpikir kritis dan kemampuan pemecahan masalah peserta didik.* Jurnal Pendidikan Tambusai, 7(3), 31712–31723.

Damayanti, S. E. P., Bektiarso, S., & Maryani, M. (2022). *Keterampilan berpikir kritis dan hasil belajar siswa dalam model pembelajaran generatif disertai media alat percobaan sederhana.* JPF (Jurnal Pendidikan Fisika) Universitas Islam Negeri Alauddin Makassar, 11(1), 1–15. https://doi.org/10.24252/jpf.v11i1.31374

Dinatha, N. M. (2017). *Kesulitan belajar siswa dalam mata pelajaran IPA terpadu.* Jurnal Pendidikan Dasar Nusantara, 2(2).

Facione, P., & Gittens, C. A. (2016). Think critically. in insight assessment.

Fadiah, R. S. (n.d.). *Pengembangan model pembelajaran PEIK (prediksi, eksperimen, inferensi, komunikasi) untuk pembelajaran IPA di SMP.*

Faizah, U., Subanji, S., & Susiswo, S. (2021). *Kemampuan bertanya siswa dalam kegiatan diskusi kelompok pada materi rasio trigonometri.* JIPM (Jurnal Ilmiah Pendidikan Matematika), 9(2), 70–84.

Fatimatuzzohrah, S., Jufri, A. W., & Mertha, I. W. (2020). *Efektivitas penerapan model pembelajaran POE (predict-observe-explain) untuk meningkatkan penguasaan konsep IPA.* Jurnal Pijar Mipa, 15(4), 351–356.

Fauziyah, D. H., & Mulyani, P. K. (2024). Development and evaluation of a digital pop-up book on the concept of force for fourth-grade science. 10(7), 3721–3730.

Hadi, S., & Kasum, M. U. (2015). *Pemahaman konsep matematika siswa SMP melalui penerapan model pembelajaran kooperatif tipe memeriksa berpasangan* (Pair Checks). Edu-Mat: Jurnal Pendidikan Matematika, 3(1).

Hasibuan, M. P., Azmi, R., Arjuna, D. B., & Rahayu, S. U. (2023). *Analisis pengukuran temperatur udara dengan metode observasi.* Jurnal Garuda Pengabdian Kepada Masyarakat, 1(1), 8–15.

Hendrowati, T. Y. (2015). *Pembentukan pengetahuan lingkaran melalui pembelajaran asimilasi dan akomodasi teori konstruktivisme Piaget.* JURNAL E-DuMath, 1(1).

Herdianto*, F., Hartono, H., & Sunarso, A. (2022). *analisis peran hands on activity dalam model predict observe discuss explain terhadap pemahaman konsep Sains SD.* Jurnal Pendidikan Sains Indonesia, 10(2), 424–439.

Huda, I. A. (2020). *Perkembangan teknologi informasi dan komunikasi (TIK) terhadap kualitas pembelajaran di sekolah dasar.* Jurnal Pendidikan Dan Konseling (JPDK), 2(1), 121–125.

Inayati, M. (2022). *Penerapan model pembelajaran berbasis masalah* (problem based learning) *dalam Pembelajaran* PAI; Teori David Ausubel, Vigotsky, Jerome S. Bruner. Al Yasini: Jurnal Keislaman, Sosial, Hukum Dan Pendidikan, 7(2), 144.

Irfan, M. (2017). Development of learning model "PODE"(predict, observe, discuss, explain) in the primary school. International Journal of Social Science and Humanities Research, 5(3), 491–498.

Islami, N. F., Ilmi, L. A., & MZ, A. F. S. A. (2024). *Urgensi pengembangan media pop-up book digital berbasis powerpoint sebagai media pembelajaran bahasa indonesia siswa sekolah dasar.* Jurnal Studi Guru Dan Pembelajaran, 7(2), 704–714.

Kartikasari, D. (2022). *Berpikir analisis melalui self question.* Penerbit P4I.

Khofiyah, H. N., & Santoso, A. (2019). *Pengaruh model discovery learning berbantuan media benda nyata terhadap kemampuan berpikir kritis dan pemahaman konsep IPA.* State University of Malang.

Kusumawati, W. T., Dewi, C., & Hadi, F. R. (2024). *Penerapan media pop up book digital terhadap kemampuan berpikir kritis siswa sekolah dasar.* Prosiding Konferensi Ilmiah Dasar, 5, 833–836.

Lastini, F., Haryanti, S., Sumardjoko, B., & Fauziati, E. (2024). *Implementasi teori perkembangan kognitif bruner pada pembelajaran matematika tentang perkalian di kelas ii sekolah dasar.* Pendas: Jurnal Ilmiah Pendidikan Dasar, 9(03), 478–494.

Lay, S., Ndoa, P. K., & Hutapea, A. K. (2024). *Penerapan teori belajar kognitif dalam pembelajaran pendidikan agama katolik menurut david ausubel.* Jurnal Serunai Administrasi Pendidikan, 13(1).

Marinda, L. (2020). *Teori perkembangan kognitif Jean Piaget dan problematikanya pada anak usia sekolah dasar.* An-Nisa Journal of Gender Studies, 13(1), 116–152.

Maritsa, A., Salsabila, U. H., Wafiq, M., Anindya, P. R., & Ma'shum, M. A. (2021). *Pengaruh teknologi dalam dunia pendidikan.* Al-Mutharahah: Jurnal Penelitian Dan Kajian Sosial Keagamaan, 18(2), 91–100.

Martika, D. (2017). *Pengaruh konsep diri terhadap kemampuan berpikir kritis siswa (Survey pasa siswa IPS Kelas XI SMA Negeri 22 Bandung)*. FKIP Unpas.

Masrifa, A., Cahyani, A. R., & Fauziyah, D. H. (2023). *Media interaktif pembelajaran IPAS.* Cahya Ghani Recovery.

Masyhud, M. S. (2021). *Metode penelitian pendidikan (ketujuh).* Lembaga Pengembangan Manajemen dan Profesi Kependidikan (LPMPK).

Mubarok, I., Nana, N., & Sulistyaningsih, D. (2020). *Analisis penerapan model pembelajaran poe2we berbasis hands on activity terhadap kemampuan berpikir kritis siswa.* Edufisika: Jurnal Pendidikan Fisika, 5(02), 104–111.

Muna, I. A. (2017). *Model pembelajaran POE (predict-observe-explain) dalam meningkatkan pemahaman konsep dan keterampilan proses IPA.* El-Wasathiya: Jurnal Studi Agama, 5(1), 73–92.

Mutiara, M. S., & Hardjono, N. (2023). *Pengembangan media digital pop-up book pada materi ekosistem untuk meningkatkan hasil belajar siswa kelas 5 SD Negeri Harjosari 01.* Journal on Education, 06(01), 5024–5038.

Nahdi, D. S., Yonanda, D. A., & Agustin, N. F. (2018). *Upaya meningkatkan pemahaman konsep siswa melalui penerapan metode demonstrasi pada mata pelajaran IPA.* Jurnal Cakrawala Pendas, 4(2), 9–16.

Nugraha, M. S., Rosdianto, H., & Sulistri, E. (2022). *Korelasi antara pemahaman konsep terhadap kemampuan berpikir kritis siswa SMA.* Phi: Jurnal Pendidikan Fisika Dan Terapan, 8(1), 29–34.

Nurhidayati, E. (2017). *Pedagogi konstruktivisme dalam praksis pendidikan Indonesia.* Indonesian Journal of Educational Counseling, 1(1), 1–14.

Prasetyowati, E. N., & Suyatno, S. (2016). *Peningkatan penguasaan konsep dan keterampilan berpikir kritis siswa melalui implementasi model pembelajaran inkuiri pada materi pokok larutan penyangga.* JKPK (Jurnal Kimia Dan Pendidikan Kimia), 1(1), 67–74.

Putra, I. B. P. A., Pujani, N. M., & Juniartina, P. P. (2018). *Pengaruh model pembelajaran kooperatif tipe jigsaw terhadap pemahaman konsep IPA siswa.* Jurnal Pendidikan Dan Pembelajaran Sains Indonesia (JPPSI), 1(2), 80–90.

Rahmayanti, S., & Setiawan, T. (2023). Learning science with digital pop-up book media. Jurnal Penelitian Pendidikan IPA, 9(10), 8085–8090.

Ramadhanti, I. (2022). *Pengaruh model predict, observe, discuss, dan explain (pode) terhadap hasil belajar kognitif siswa pada mata pelajaran IPA.* Universitas Pendidikan Indonesia.

Rochmad, R., Kharis, M., & Agoestanto, A. (2018). *Keterkaitan miskonsepsi dan berpikir kritis aljabaris mahasiswa s1 pendidikan matematika.* PRISMA, Prosiding Seminar Nasional Matematika, 1, 216–224.

Suciono, W. (2021). *Berpikir kritis (tinjauan melalui kemandirian belajar, kemampuan akademik dan efikasi diri).* Penerbit Adab.

Sugiyono. (2019). *Metode penelitian kuantitatif, kualitatif, dan R&D (kedua).* Alfabeta.

Suryani, E. (2019). *Analisis pemahaman konsep? Two-tier test sebagai alternatif.* CV. Pilar Nusantara.

Susilawati, A., Sujana, A., & Ali, E. Y. (2025). *Pengembangan pop-up book digital untuk meningkatkan pemahaman konsep kelas IV materi bagian tumbuhan dan fungsinya.* Ideguru: Jurnal Karya Ilmiah Guru, 10(1), 158–164.

Syamsuadi, M. I. (2017). PODE (predict, observe, explain discus, explain).

Wardani, R. P. (2019). *Pengembangan perangkat pembelajaran penguasaan konsep IPA Siswa SD Kelas V melalui pendekatan saintifik.* Alpen: Jurnal Pendidikan Dasar, 3(1).

Widiastuti, W., & Kania, W. (2021). *Penerapan metode diskusi untuk meningkatkan kemampuan berfikir kritis dan pemecahan masalah.* Jurnal Pendidikan Ekonomi Indonesia, 3(2), 259–264.

Wiguna, C. S. (2018). *Pengaruh model pembelajaran POE terhadap pemahaman konsep dan kemampuan berpikir kreatif peserta didik.* Jurnal Geografi Gea, 13(1).