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The Effectiviness of The Generative Learning Model with Cognitive Conflict Strategy on Students' Science Literacy in Fluid Material in Grade XI

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ABSTRACT

Science literacy is an important skill in modern science education, involving understanding concepts, reasoning scientifically, and applying science in everyday situations. However, the level of science literacy among students in Indonesia is still low, as seen in the 2022 PISA results, which are below the global average. This shows the need for learning models that can increase cognitive participation and form a deep conceptual understanding. Generative learning models, which focus on knowledge construction through the integration of prior knowledge with new learning experiences, are considered suitable for improving science literacy, especially when combined with cognitive conflict strategies. This study aims to examine the impact of a generative learning model that uses cognitive conflict strategies on students' science literacy on the topic of Fluids in Grade XI Phase F. This study applied a quasi-experimental method with a single group pretest-posttest design. The results show an increase in the average score from 63.75 on the pretest to 91.25 on the posttest. The hypothesis test produced a significance value of 0.000 (less than 0.05) with an N-Gain of 0.7667, which is classified as high. These findings prove that the generative learning model with cognitive conflict strategies is effective in improving students' science literacy.

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INTRODUCTION

Twenty first century learning is an approach that emphasizes the importance of competencies to prepare students to face the complexity of global issues, advances in digital technology, and dynamic social changes. Education in this era requires students not only to master academic concepts but also to develop higher-order thinking skills. These skills include critical thinking, problem-solving, scientific communication, as well as digital literacy and scientific literacy. One of the most fundamental competencies in science

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education is science literacy. Science literacy encompasses the ability to understand scientific concepts, apply the scientific process, interpret data, and critically and reflectively evaluate evidence-based arguments (Rohmaya, 2022). A good understanding of science enables individuals to apply that knowledge in solving problems encountered in daily life (Rahayu, 2019). This expectation can be realized if students have adequate science literacy skills.

Science literacy is an individual's ability to understand and apply scientific concepts in solving real-world problems related to science and technology in everyday life. Additionally, science literacy is one of the key competencies of the 21st century, reflecting an individual's capacity for critical thinking, scientific reasoning, and applying scientific understanding in real-life contexts (Shofiyah et al., 2025). In 21st-century science education, science literacy and character education are two important dimensions that are mutually integrated in the development of students' competitive potential (Syahidi et al., 2023). Science literacy encompasses not only conceptual understanding but also skills in evaluating scientific information, interpreting data, and making decisions (OECD, 2017). Mastering science literacy is crucial, not only in an academic context but also in shaping scientifically aware citizens who think reflectively and take responsibility for global science and technology issues.

A scientifically literate society can be achieved through education, so education must be able to equip students with the basic scientific literacy skills they need (Anggi et al., 2019). However, the reality is that the scientific literacy of students in Indonesia is still far from ideal. The average science literacy score of Indonesian students is 398, which is far below the OECD norm of 500. In the 2022 PISA (Programmed for International Student Assessment) report released by the OECD, Indonesia ranks 68th out of 81 countries. This indicates that many students are still unable to think scientifically, understand scientific concepts comprehensively, and apply them in real-world situations.

Based on PISA results, science literacy among students in Indonesia is still relatively low. Several factors contributing to this low science literacy include the selection of inappropriate textbooks, the emergence of conceptual errors, non-contextual learning, and the learning environment and atmosphere (Fuadi et al., 2020). This finding is reinforced by (Yusmar & Fadilah, 2023), who add that the low quality of teachers in science literacy and the lack of supporting facilities for scientific practice are also critical factors. Additionally, teaching that focuses more on memorizing material without supporting the scientific thinking process makes it difficult for students to develop comprehensive science literacy. Low reading interest and limited access to relevant learning resources further exacerbate this situation (Suparya et al., 2022). Thus, science education that is not contextually relevant is one of the main causes of low science literacy among students, particularly in physics education.

Based on observations conducted by researchers at SMAN 4 Padang, researchers provided instruments in the form of science literacy questions to assess students' initial science literacy abilities. The results of students' science literacy are shown in Table 1.

Table 1. Science Literacy at SMAN 4 Padang

Science Literacy Indicators	SMAN 4 Padang
Explaining scientific phenomena	37%
Evaluating and designing scientific knowledge	39%
Interpreting scientific data and evidence	40%
Average	39%

Overall, students' science literacy achievement was only 39%, indicating that most students had not yet mastered science literacy competencies well. This low level of science literacy indicates the need for innovation in learning models, methods, and media to improve students' science literacy skills.

This problem is particularly evident in physics education, which is actually a subject with great potential for developing students' scientific literacy. Physics not only teaches scientific concepts but also requires critical thinking skills, problem-solving abilities, and an understanding of the relationship between theory and real-world phenomena. As a result, many students are only able to memorize without deeply understanding the concepts, especially in abstract and complex material such as fluids. Fluid material in physics learning has proven to be a serious challenge for many high school students (Kiranti, 2019). The abstract nature of physics material requires an understanding of mathematical concepts and higher-order thinking skills (Rahmatiah et al., 2016). Additionally, a teaching approach that remains focused on the educator results in a lack of active student involvement in the learning process (Setiawati et al., 2018). Misconceptions about static fluids are also very common, for example, regarding Pascal's Law (39%) and Archimedes' principle (45.7%) (Kurniawan, 2023). Therefore, physics learning at the high school level needs to be developed, especially in terms of science literacy, through the application of innovative and contextual approaches.

The learning approach that still focuses on educators and does not actively involve students in the process of constructing their own knowledge is one of the factors causing low science literacy. In many high schools, physics learning processes tend to be dominated by teacher lectures, while students play a passive role as listeners. This lecture- and discussion-oriented learning approach makes students passive and struggles to develop critical thinking skills (Sudirman, 2022). This phenomenon is reinforced by (Agustina et al., 2023), who state that teachers at the high school level still predominantly use the lecture method and have not effectively integrated 21st-century learning strategies. Therefore, a learning model is needed that can encourage active student participation in the knowledge creation process and empower their thinking abilities.

To support students in creating knowledge through active engagement, interaction, and reflection, constructivist learning strategies are needed, one of which is generative learning. Generative learning is a learning model that seeks to integrate new ideas with the knowledge schemas already possessed by students. This model is based on constructivism and places greater emphasis on the active integration of new knowledge with prior knowledge (Moma, 2013). Generative learning has four core elements: motivation, the learning process, knowledge creation, and the generation process (Akmam, 2019). By exposing learners to scientific facts or events that challenge their assumptions, this model helps them identify and evaluate their initial thoughts, experience cognitive conflict, and develop new, more scientific understandings. In this context, the generative learning model combined with cognitive conflict strategies is a good alternative for teaching content effectively at the secondary school level.

Although research integrating these two approaches to achieve science literacy is still limited, a number of previous studies have demonstrated the effectiveness of generative models and cognitive conflict strategies. Although they did not specifically evaluate science literacy, (Agustin et al., 2024) found that generative models based on cognitive conflict can improve learning outcomes regarding waves among high school students. Additionally, although cognitive conflict was not used as the primary strategy, (Hasanah Parni & Dwi Sundari, 2023) demonstrated that a generative model with a contextual approach successfully improved understanding of physics in the context of dynamic fluids. Although there are still few studies that have tested both approaches in an integrated manner within the context of improving science literacy, these findings indicate the significant potential of generative approaches and cognitive conflict strategies in advancing scientific understanding.

By integrating cognitive conflict strategies and generative learning models into a cohesive model, this study introduces a new approach to the learning process. Through this combination, students are expected to overcome misunderstandings, develop scientific thinking, and apply physics principles contextually. This study uses a quasi-experimental method to test the effect of the generative learning model combined with cognitive conflict strategies on students' science literacy, particularly in fluid mechanics. The focus of this study is on 11th-grade students in Phase F-9 at SMAN 4 Padang.

Based on this background, the problem addressed in this study is an effect of the generative learning model combined with cognitive conflict strategies on student literacy in fluid mechanics in grade XI at SMAN 4 Padang. The application of the generative learning model with a cognitive conflict approach through the stages of initial knowledge discovery, conceptual confrontation, experimental reconstruction of scientific understanding, and conceptual reflection is considered an appropriate solution to address this issue. This strategy is expected to have a significant impact on improving science literacy, as it can enhance students' cognitive engagement and help them develop meaningful conceptual knowledge.

METHODS

This study uses quantitative research with a quasi-experimental approach. Quasi-experimental is a type of preliminary experiment that aims to determine the impact of an intervention on a dependent variable, but does not fully meet the standards of a pure experiment because it does not involve a control group and does not randomize the research subjects. The design applied in this study is a One-Group Pretest-Posttest Design, which involves a group of students whose initial abilities are measured (pretest), then given an intervention in the form of a specific learning model, and measured again with a posttest (Sugiyono, 2013). The difference between the pretest and posttest scores is used to assess the effect of the intervention on student learning outcomes.

This design is considered appropriate because it allows researchers to observe changes that occur after the intervention is given, even without comparison with a control group. The results of this study are expected to provide an initial picture of the impact of the generative learning model with cognitive conflict strategies on improving students' science literacy. The research design can be seen in Table 2 below:

Table 2. Research Design

Pretest	Treatment	Post-test
O_1	X	O_2

Source: Sugiyono (2013)

Description

O_1 : Initial test score

O_2 : Final test score

X : Treatment using Generative Learning Model with Cognitive Conflict Strategy

The first step is to determine the group that will be used as the experimental group. In this research design, only one group is used, so a control group is not necessary. Before being given the intervention, the experimental group is given a pretest, followed by the intervention using a generative learning model with a cognitive conflict strategy on the topic of Fluids. The intervention given to the experimental group consists of six learning sessions.

This research was conducted in three main stages that were carried out sequentially. The first stage was preparation, which included providing appropriate teaching materials, creating research instruments, and requesting permission to conduct research at the school. This stage was intended to ensure that all research requirements were met from an administrative and academic perspective. The second stage was implementation, which began with administering a preliminary test to students to assess their level of science literacy before the intervention was given. After that, the learning process was carried out using a generative learning model combined with cognitive conflict strategies on the topic of fluids. The implementation stage was concluded with a final test to see the development of students' science literacy after the learning model was applied. The final stage was data analysis, which involved examining the results of the initial and final tests to determine the effectiveness of the learning that had been carried out.

The sample in this study is a segment of the population that reflects the characteristics of the entire population. The sample selected was one class, XI Phase F-9, consisting of 31 students. The sample was selected using purposive sampling, taking into account practical aspects and the suitability of the learning time at school. Class XI Phase F-9 was selected as the experimental class that received an intervention in the form of a generative learning model combined with a cognitive conflict strategy. The selection of only one class was adjusted to the research design used, namely a single group pretest-posttest design. This design did not require a control group, so all students in the class became research subjects. In this way, all class members were used to assess how effective the intervention was in improving students' science literacy.

The instruments used in this study consisted of a series of science literacy questions compiled based on relevant science literacy indicators. The instruments were developed in accordance with the Fluids material for 11th grade students. These instruments were adapted from research conducted by the instruments underwent a validation process to ensure their suitability for use in research activities. In addition, these instruments were also found to be practical in their implementation. The adapted instruments were considered effective in accurately measuring students' science literacy levels.

The technique used to analyze data in this study is the N-Gain test. The N-gain score aims to evaluate the effectiveness of using a particular method or treatment. The N-gain score test procedure is carried out by calculating the difference between the pre-test and post-test scores, or the gain score. In this way, we can determine whether the application of a particular method can be considered effective. According to Hake (1999), the N-gain score can be calculated using the following formula:

$$N\ Gain = \frac{Skore\ Posttest - Skore\ Prettest}{Skore\ Ideal - Skore\ Pretest}$$

Note: the ideal score is the maximum value.
The normalized N-Gain score results are divided into three categories, namely:

Table 3. Normalized Gain Criteria

Percentage	Classification
N-Gain > 7.0	High
3.0 ≤ N-Gain ≤ 7.0	Medium
N-Gain < 3.0	Low

RESULTS AND DISCUSSION

Results

This study was conducted at SMA Negeri 4 Padang from April 14 to May 27, 2025, involving one class as the experimental class. Class XI-9 Phase F received learning through a generative model based on cognitive conflict for Fluid material. To assess initial science literacy skills, students were given a pre-test in the first meeting, while a post-test was conducted in the last meeting to see the development of science literacy after the intervention. The scores and descriptive analysis of the pre-test and post-test of class XI-9 Phase F students are shown in Table 4 below.

Table 4. *Pre-test* dan *Post-test* Result

	N	Maximum Value	Minimum Value	Mean	Median	Standard Deviation
Pre-test	31	77.27	38.63	62.90	63.64	7.46
Post-test	31	97.73	81.82	91.78	93.18	4.76

From Table 2, the analysis shows a very significant increase between students' pretest and posttest scores. The average score rose from 62.90 on the pretest to 91.78 on the posttest, indicating much better mastery of the material after the intervention was given. This increase is also supported by an increase in the lowest score from 38.63 to 81.82, which indicates that almost all students achieved high learning outcomes, not just a few outstanding students. In addition, the decrease in standard deviation from 7.46 to 4.76 shows that student learning outcomes are more evenly distributed and stable. Overall, these data show that the learning applied was not only effective in improving learning outcomes, but also able to reduce differences in ability among students.

The results of the data analysis presented in the pre-test and post-test tables show that the average science literacy score of students before the implementation of the generative learning model with cognitive conflict strategy was 62.90. This score indicates that the level of science literacy of students is still considered adequate, thus presenting a significant opportunity for improvement. After the implementation of the generative learning model combined with the cognitive conflict strategy, the post-test results showed a significant improvement. The average post-test score reached 91.78, indicating that most students have achieved a high level of science literacy. This improvement serves as evidence that the implemented learning model successfully created a learning environment that encouraged students to evaluate and revise their initial understanding, as well as build more scientific and contextual knowledge.

The results of the pretest and posttest show the development of students' science literacy skills in each science literacy indicator. This analysis was conducted to observe the achievements and changes in students' abilities in each indicator after implementing a generative learning model based on cognitive conflict. Students' science literacy scores based on each indicator are shown in Table 5 below:

Table 5. Science Literacy Scores for Each Indicator

Science Literacy Indicators	Pre-Test	Post-Test
Explaining scientific phenomena	61.69%	83.13%
Evaluating and designing scientific knowledge	70.97%	83.68%
Interpreting scientific data and evidence	58.06%	80.65%
Average	63.57%	82.82%

From Table 3, it can be seen that all science literacy indicators improved after the implementation of the generative learning model based on cognitive conflict. The indicator explaining scientific phenomena rose from 61.69% in the pretest to 83.13% in the posttest, indicating a strengthening of students' conceptual understanding. The indicator evaluating and designing scientific knowledge increased from 70.97% to 83.68%, reflecting the development of evaluative thinking and scientific solution design skills. The most significant increase occurred in the indicator of interpreting scientific data and evidence, from 58.06% to 80.65%, which illustrates the growth in the ability to analyze data and draw conclusions based on evidence. Overall, the average science literacy score rose from 63.57% to 82.82%, proving that this learning model is effective in improving science literacy achievement across all indicators.

The results of the analysis of the table show that students' science literacy skills have improved significantly in all indicators after the learning process was implemented. The increase in the percentage of indicators explaining scientific phenomena shows that students are increasingly able to logically connect concepts with real events. Improvements in indicators evaluating and designing scientific investigations reflect the development of critical thinking skills and the ability to systematically design scientific processes. Meanwhile, the surge in the ability to interpret scientific data and evidence shows that students no longer simply look at numbers, but have begun to understand the meaning behind the data. Overall, the increase in average scores indicates that the learning process implemented is effective in shaping more comprehensive scientific literacy, from understanding concepts to analyzing and drawing scientific conclusions.

Furthermore, to see the effectiveness of the generative learning model using cognitive conflict strategies, calculations were performed using the N-Gain formula. The N-Gain Score values can be seen in the following Table 6:

Table 6. N-Gain Score

	N	Maximum Value	Minimum Value	Mean	Standard Deviation
N-Gain	31	0.94	0.52	0.77	0.107

The analysis results showed that out of 31 students, the N-Gain values ranged from a minimum of 0.52 to a maximum of 0.94. The mean N-Gain was 0.77, with a standard deviation of 0.107. An N-Gain mean of 0.77 falls into the high category. Therefore, the improvement in students' science literacy after the implementation of the generative learning model combined with cognitive conflict strategies also falls into the high category. This finding indicates that the applied learning model is effective in improving students' conceptual understanding and science literacy skills. Additionally, the relatively small standard deviation (0.107) indicates that the variation in N-Gain scores among students is not too significant, meaning that most students experienced a fairly consistent improvement.

Discussion

The results obtained from this study were used to evaluate the achievement of the research objectives, namely to determine whether there was an effect of the cognitive conflict-based generative learning model on the science literacy of grade XI-9 Phase F physics students at SMA Negeri 4 Padang. The research findings indicate that the application of the generative learning model combined with cognitive conflict strategies has a significant positive impact on students' science literacy in fluid mechanics.

This is reflected in the increase in the average pretest score from 62.90 to 91.78 on the posttest, indicating progress in students' science literacy after the intervention. This increase in scores indicates that students who previously had only moderate mastery of the material were able to achieve significant development in building scientific knowledge in a more comprehensive and structured manner after participating in learning process that emphasized cognitive conflict and understanding construction. These results are consistent with domestic research stating that generative learning models are effective in improving science literacy because they encourage students to actively connect prior knowledge with new concepts (A. Akmam et al., 2025). In addition, cognitive conflict strategies have been proven to reduce misunderstandings and increase students' cognitive participation through reflection and reformulation of conceptual understanding (Fajri & Wantika, 2022; Hendini et al., 2023). Other studies also show that learning that emphasizes cognitive conflict and independent knowledge construction contributes significantly to the development of students' scientific thinking skills and science literacy (Effendi et al., 2023; Hasanah Parni & Dwi Sundari, 2023). Thus, the findings of this study are in line with and reinforce the results of previous national studies, namely that combining the generative learning model with cognitive conflict strategies is an effective approach to improving students' science literacy.

Analysis of science literacy indicators shows progress after the implementation of a generative learning model based on cognitive conflict, indicating the effectiveness of this model in developing students' science literacy skills. The increase in the indicator explaining scientific phenomena from 61.69% to 83.13% illustrates a strengthening of conceptual understanding, which is consistent with the findings of (Mufit & Dhanil, 2024) that generative learning helps students build conceptual understanding by connecting prior knowledge with real phenomena. In the indicator of evaluating and designing scientific knowledge, the increase from 70.97% to 83.68% reflects the development of evaluative thinking and scientific solution design skills, as reported by (Devana et al., 2025), who stated that cognitive conflict strategies encourage students to critically reflect on the ideas and solutions proposed. The largest increase in the indicator of interpreting scientific data and evidence from 58.06% to 80.65% shows that learning that emphasizes cognitive conflict is effective in training the ability to analyze data and draw conclusions based on evidence, in line with the results of research by (Fitri & Putra, 2023). In general, the increase in the average science literacy from 63.57% to 82.82% reinforces the findings of (Zainuddin; Riana, Dwi Astuti; Misbah, Misbah; Wati, Mustika; Dewantara, 2020) that the combination of generative learning and cognitive conflict models contributes significantly to the improvement of students' science literacy in all indicators.

In addition, N-gain analysis shows that the average N-gain value of students reached 0.77, which is in the high category. This finding indicates that the improvement that occurred was not only statistically significant but also practically effective. This was due to the majority of students showing a high increase in science literacy skills after the implementation of the learning model. Overall, these results reinforce the finding that structured cognitive conflict within the generative learning syntax can create an active, reflective, and meaningful learning process. As a result, this directly impacts the improvement of students' science literacy. These findings support the view that learning that emphasizes thinking, reflection, and problem-solving activities is more effective than conventional learning (Rahayu, 2019). Thus, the N-Gain results in this study are not isolated but are in line with recent empirical evidence showing that innovative learning strategies can significantly and sustainably improve the quality of student learning outcomes.

By applying a generative learning model that integrates cognitive conflict strategies, students can be more active in expressing ideas, conducting experiments, and completing tasks and exercises related to the application or problem-solving of physics. Such learning encourages students to actively discover facts, concepts, and theories through observation. As a result, the knowledge gained by students during the learning process is reflected in their science literacy skills, which demonstrate a fairly good quality. This is due to students' experiences in expressing ideas and reconstructing knowledge based on the learning experiences they have undergone.

By applying a generative learning model that integrates cognitive conflict strategies, students are given the challenge and opportunity to discover problems and express their ideas. This aims to develop science literacy that is relevant to their various experiences. As a result, understanding of scientific literacy regarding various natural phenomena will be internalized and contribute to the understanding of physics concepts. Therefore, the generative learning model with cognitive conflict strategies has proven to be highly effective in enhancing students' scientific literacy.

CONCLUSION

Based on the results of the research and discussion, it can be concluded that the generative learning model that integrates cognitive conflict strategies has been proven effective in improving students' science literacy in fluid material. Evidence of this effectiveness can be seen from the increase in the average science literacy score, which increased from 57.02 on the pretest to 90.08 on the posttest. The results of the analysis of students' science literacy based on science literacy indicators show that science literacy increased from 63.57% to 82.82%. In addition, the results of statistical analysis using the N-Gain test show an average value of 0.7667, which indicates that the increase in science literacy is in the high category. These findings indicate that the application of the generative learning model with cognitive conflict strategies can be an appropriate alternative to improve students' science literacy.

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