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Effective Learning to Build Science Literacy: A Meta-Analysis Study

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Abstract

The science literacy of students in Indonesia, based on the PISA 2022 assessment, is categorized as low. Indonesia ranks 67th out of 81 countries, indicating that science literacy still needs significant improvement. This study aims to identify the most effective learning model for improving science literacy and to understand its characteristics. The method used is meta-analysis, consisting of four stages: data collection, data reduction, data presentation, and conclusion drawing. The data analyzed were obtained from nine national journal articles published between 2020 and 2024, sourced from Google Scholar, Publish or Perish, Garuda, and Sinta. The results of the analysis show that the Discovery Learning model has the highest effect size value of 4.14, indicating that it is highly effective in improving science literacy. This model actively involves students in the process of discovering concepts through observation, data processing, and drawing conclusions, thereby developing critical thinking skills and the ability to solve problems independently. The average effect size values across Indonesian regions vary significantly, with western Indonesia showing an average of 1.51 and eastern Indonesia 1.64. The average effect size at different education levels was found to be 2.06 at the junior high school level and 0.90 at the high school level. Similarly, the effect size for the topic of interactions among living things taught to junior high school students was 4.14, while for high school students, the effect size for the topic of climate change was 2.42.

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INTRODUCTION

Science literacy means being able to take part in dealing with scientific issues and ideas by using what you know to ask questions, explain things scientifically, draw conclusions, and think carefully (Fuadi et al., 2020). Using the right approaches and strong technology support, science literacy is important for building and improving students' 21st-century skills like critical thinking, creativity, teamwork, and communication (Lestari, 2020). Science literacy is very helpful for learners because it helps them become active and responsible citizens who can use their science knowledge and skills in real-life situations (Zainudin et al., 2024).

Students gain a lot from science literacy because it helps them be more involved in society and use their science knowledge and processes in daily life (Zainudin et al., 2024). A country is considered developed when its people have high quality. Education is closely linked to a country's development and challenges. Science literacy is very important in education, as one of the major issues in Indonesia is the low level of science literacy among students, as

shown by PISA results over the years (2000-2018) (Safrizal, 2021). Indonesia ranks 74th out of 79 countries in the 2018 International Student Assessment (PISA) (Hewi & Shaleh, 2020). The results show that Indonesian students have very poor math skills, including the ability to reason, solve problems, and communicate mathematically (Lestari & Annizar, 2020). One effective way to improve students' science literacy is by helping them understand how science works in everyday life and think about solutions to daily problems. Learning that is centered on students can help improve their science literacy, allowing them to use the knowledge they've learned to solve real-life issues (Hanum & Sari, 2023).

It is very important to assess science literacy to understand what learners know (Arief, 2015). This includes finding problems, searching for new information, explaining scientific events, and making conclusions based on evidence related to scientific issues (Narut & Supradi, 2019). Doing this helps improve the quality of education in Indonesia and makes it more competitive with other countries (Pratiwi et al., 2019). The ability to learn science literacy in Indonesia is still relatively low, this is due to a lack of understanding of the concept of science learning. Because of this inability, students simply memorize the material without understanding it. As a result, the learning process loses its main purpose, which is to encourage learners to think critically, understand deeply and relate what they learn to real-world situations (Utami et al., 2022).

The results of the PISA study on Science Literacy Ability in Indonesia in 2022 with an average score in Indonesia of 383, and an average score of PISA 500 with a ranking of 67 out of 81 countries. Despite the progress in science literacy in Indonesia, the level of science literacy is still relatively low. Low science literacy is caused by a learning process that is not supportive in developing these abilities. In addition, the assessment techniques commonly used in schools can be the cause of the low PISA study in Indonesia (Pratiwi et al., 2019).

Improving science literacy through several efforts, one of which is by using learning models. Therefore, a meta-analysis study is needed to map the results of previous research related to effective strategies for science literacy that are interpreted based on the region and level of education as well as learning materials.

RESEARCH METHODS

This study uses a quantitative approach with a type of meta-analysis research method that allows researchers to combine findings from various studies to reach stronger and more comprehensive conclusions. The data used consisted of scientific articles found in Google Scholar, Publish or Perish, Garuda, and Sinta. Coding data is the tool used in this study.

This study applies the PRISMA approach to ensure that the stages of searching, selection, assessment, and combining study results are carried out systematically and transparently. This approach makes it easier for researchers to select articles based on inclusion and exclusion criteria, so that only relevant and high-quality studies are included in follow-up analysis.

The inclusion criteria for the article search were as follows: the study must involve learning models that can enhance scientific literacy, be published between 2020 and 2024, be indexed in Sinta 1–5, and present statistical data that include the average values of both the experimental and control classes along with the standard deviation. Conversely, the exclusion criteria specified that articles were omitted if their titles did not match the chosen keywords, were published before 2020, focused on strategies rather than learning models, or were not indexed in Sinta.The results of

the article search get several articles that will be presented in the following PRISMA diagram:

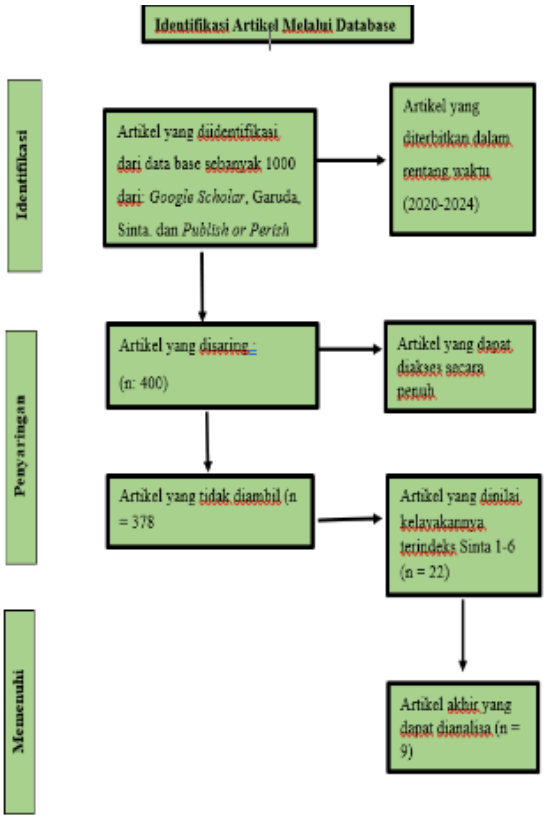

Figure 1. PRISMA Diagram

The articles used in this study came from national journals indexed by SINTA. Articles obtained through Google Scholar, Publish or Perish, Garuda, and SINTA with keywords Learning model and Science Literacy. Of the 400 articles found, 9 met the criteria. Data analysis uses Cohen's formulas and statistics to calculate and interpret effect size, as described in Table 1 (Cohen et al., 2009).

Table 1. Cohen's Effect Size Criteria

Cohen's Standard	Effect Size	Percentile Standing	Percent Of Nonoverlap
Large	0,6-2,0	73-97,7	47,4%-81,1%
Medium	0,3-0,5	62-69	21,3%-33,0%
Small	0,0-0,2	50-58	0%-14,7%

RESULTS AND DISCUSSION

This study used meta-analysis to find out how much different learning models affect the improvement of science literacy. This study not only looked at the overall influence, but also looked at how these influences differ based on educational level, the region where the research was conducted, the year of the research and the type of learning model used. In other words, the purpose of this study is to provide a more comprehensive picture of how effective the learning model is in improving students' science literacy. The results of the literature review obtained several articles that had been filtered through a prism diagram, then the articles were calculated to obtain the effect size result. The effect size results can be seen in the following table:

Table 3. Cohen's effect size criteria

Year	Code	Researchers	Education Level	Territory	Learning model	Material	ES
2020	A1	Alatas & Fauziah (2020)	SMA	Jakarta (West)	Problem Based Learning	The concept of global warming	2,42
2020	A6	Pujiasih et al. (2020)	SMP	Lampung (West)	Discovery Learning	Interaction of living things	4,14
2022	A4	Aini (2022)	SMA	Depok (West)	Problem Based Learning	Fungi	0,78
2022	A5	Pratama & Zilhakim (2022)	MTs/SMP	Bengkulu Selatan (West)	PBL Based on Blended Learning	Reproductive system in humans	0,80
2022	A7	Fuadina et al. (2022)	SMP	Jember (West)	Guided Inquiry	Wave	0,81
2020	A9	Ade et al,. (2023)	SMA	Jawa Timur (West)	Group Investigation (GI)	Wave	0,40
2023	A2	Ade et al,. (2023)	SMP	Bali (East)	Independent inquiry	Ecosystem	2,50
2023	A3	Winda et al,. (2023)	SMA	Sulawesi Tenggara (East)	Learning Cycle 7e	Effort and energy	0,12
2024	A8	Evi et al,. (2024)	SMA	Kediri (West)	Problem Based Learning	Environmental changes	0,78

The results of the Effect Size calculation can be seen in the following figure: society.

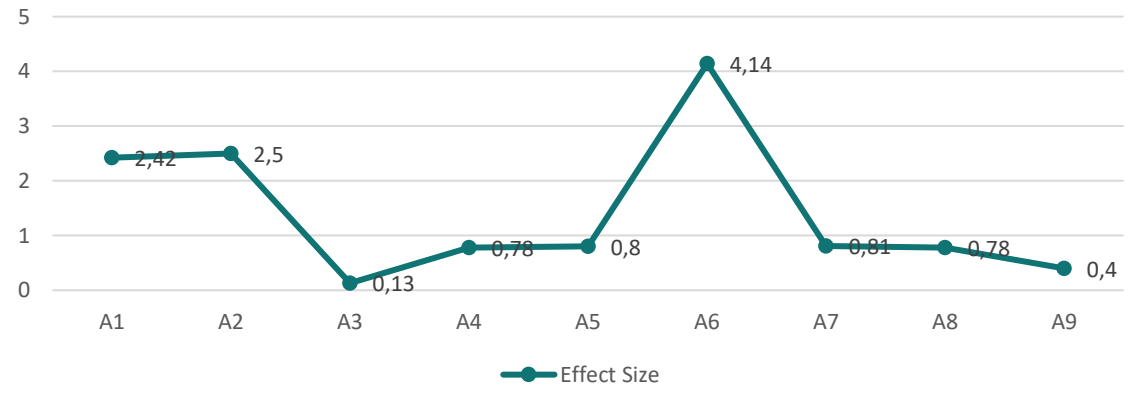

Figure 2. Effect Size Results

The Most Effective Learning Model for Improving Science Literacy in Indonesia

Based on the results of the calculation of the effect size value presented in Table 2, it was found that there are seven learning models that can improve students' science literacy. These learning models include Problem Based Learning, Free Inquiry, Learning Cycle 7e, PBL Based on Blended Learning, Discovery Learning, Guided Inquiry, and Group Investigation (GI). Of the seven learning models, there are seven learning models that fall into the high effect category and two learning models that fall into the medium effect category .

Value effect size shows that the learning model discovery learning can increase science literacy with a score of 4.14. The data is seen as a whole from the results of the calculation of the value effect size of the type of learning model that can help improve science literacy. In the learning model discovery learning, learners are asked to do various activities to discover their own ideas. Type Discovery Learning It is suitable to be applied in the classroom because it can improve science literacy and student learning outcomes such as identifying problems, searching for data, processing data, and drawing their own conclusions about problems found in the field (Kulsum et al., 2020).

The research is also supported by research from Izzatunnisa et al. (2019), according to Izzatunnisa "The discovery learning model is a model that is quite effective in using because it can increase student participation during the learning process, train and develop students' critical and creative thinking, train and develop students' procedural knowledge, and be able to shape and improve students' science literacy skills."

The effect size value shows that the free inquiry learning model can improve science literacy with a value of 2.50. The data is seen from the overall results in the table above. The free inquiry learning model is an effective approach in developing high-level thinking skills in students. In the inquiry-based learning process, students are actively involved in exploring problems through systematic investigation, thinking critically, logically, and analytically. This model encourages students to become learners who are able to develop solutions creatively and in-depth based on observation and experience (Zulfiani et al., 2017). In line with the results of the research from gormally, according to Gormally et al. (2009) and Haerani et al. (2020), free inquiry learning improves students' science literacy skills.

Value effect size shows that the learning model problem based learning can increase students' literacy with a score of 2.42. The data is seen from the overall value effect size. Problem-based learning model (problem-based learning) is a learning approach designed to hone various types of students' intelligence, which is needed to face real-world challenges. This model puts students in situations that require them to think critically, creatively, and be able to analyze and solve problems effectively.

Research from Juleha et al. (2019) supporting this research by stating that the problem-based learning model has a significant influence on improving students' ability in science literacy in all fields. These findings are in line with the findings of the study (Rubini et al., 2016), which also found that problem-based learning models have an influence on students' ability in science literacy in all fields. Problem-based learning helps students explain scientific phenomena, propose and design scientific research, and interpret scientific data and evidence. Using this model, students are trained to solve problems through structured steps.

Learning model guided inquiri Getting the criteria effect size by 0.81. The data is seen from the value table effect size

Overall. Guided inquiry learning (guided inquiri) is a learning method in which the teacher gives students structured direction or guidance during the learning process. In this model, the teacher remains actively involved in directing the inquiry process. This ensures that students are not completely independent of their own free will, but rather give them the opportunity to think critically and gradually find solutions to their problems (Fitri & Fatisa, 2019).

The problem-based learning model based on blended learning obtained an effect size criterion of 0.80. This data can be seen from the effect size table above. Using the problem-based learning model, students can identify the need for the problem-solving process by working individually or in groups. Thus, this model allows students to solve problems related to daily life. With a combination of blended learning approaches, problem-based learning encourages learners to apply it in their daily lives. By implementing blended learning as part of the PBL model in learning, blended learning will help guide students in improving their science literacy skills (Ulandari & Mitarlis, 2021).

Value effect size above in the problem-based learning model of 0.78 with problem-based learning and project-based learning methods. Research conducted by Aini (2022) stated that the results of the study showed that students in class X had different science literacy results when the PBL and PJBL models were applied to the concept of fungal (fungus) material. These results show that the application of the two learning models is different.

The researchers examined variations in science literacy outcomes in each aspect of the 2006 PISA indicators. The science literacy assessment is carried out using assessments based on PISA 2006. Competence, content, context, and attitude are the four components that make up the assessment indicator. After the data was collected, they were processed statistically and the results showed that there were differences in science literacy, among which students used the PBL and PJBL learning models. The 2013 curriculum document recommends the PBL and PJBL models as learning models that can improve students' science literacy. The second model shows that there are differences in students' literacy outcomes. This is due to the difference in the learning syntax components of the two models, so that students gain different abilities when using the two models.

The effect size value of the Learning Cycle 7E learning model received a value of 0.78, the same as the value of problem-based learning and project-based learning. The cycle 7E learning model is a student-centered, or student-centered, learning model. This model consists of various stages of activities that are arranged in such a way that students can actively participate in the learning process and acquire the necessary competencies (Fembriani & Rofisian, 2018). As stated by Sumiyati et al. (2016), learning that uses the cycle 7E learning model requires students to learn the material through work and thinking, so that the knowledge they gain comes from their own hands-on experience.

Research conducted by Qulud et al. (2015) found that students in the classroom who used the 7e learning cycle learning model significantly improved their science literacy skills compared to students who did not use the 7e learning cycle model. These findings are supported by several studies, one of which is a study conducted by Khotimah et al. (2018) which shows that students have different science literacy skills in classes that use the 7E learning cycle model compared to classes that use the direct instruction model. This study also shows that the implementation of the 7E learning cycle

model is very good, and students have high motivation to learn.

The group investigation (gi) learning model gets a score effect size by 0.78. Research conducted by (Ary, 2022) states that because the Group Investigation(GI) is a group-based learning model, the science literacy skills of students learning through PhET virtual simulations are enhanced. where students have the opportunity to examine the problem together and actively participate in the discussion while using it. In the learning model Group investigation (GI), students not only obtain information directly from the teacher, but they can also build visual knowledge through discovery activities with the help of interactive media, such as PhET.

Thus, this activity allows students to exchange ideas and contribute ideas to each other through communication with group friends or between groups. This is in line with research conducted by Vhalery (2019) that indicates that the application of the model Group investigation (GI) impacts how students perform their study assignments. Students who use GI can transform a rigid classroom atmosphere into a more interactive one. This can improve social interaction with friends and teachers.

Learning model problem based learning Getting Points effect size by 0.12 in the Problem-Based Learning Learning model, the value of effect size It is included in the medium category. Based on the results of research, data analysis, and discussion, it can be concluded that the problem-based learning model significantly affects students' science literacy skills. This may be because the stages of PBL allow students to participate more actively in the learning process. These results can be seen from the improvement of students' science literacy skills in the experimental and control classes, with N-Gain=0.58 and N-Gain=0.38, respectively. Value difference effect size Due to the increase in moderate categories, students have the ability to explain scientific phenomena, find and gather relevant information, and combine their own knowledge to find relevant solutions to the problems at hand (Zulfa et al., 2022).

Characteristics of Effective Learning Models for Improving Science Literacy

A variety of innovative learning models such as Discovery Learning, Inquiry Bebas, Problem Based Learning, Inquiry Terpandu, PBL-based Blended Learning, Learning Cycle, and Group Investigation have similarities that originate from the theory of constructivism. This theory emphasizes that students need to build knowledge through direct experience, active participation, and social interaction. In practice, students become the focus of the learning process (student-centered learning), while teachers function as facilitators who guide, provide space for exploration, and assist students in finding solutions to real problems. These models also emphasize the process of inquiry and problem-solving as the core of learning.

Learners are encouraged to recognize problems, formulate questions, develop research plans, analyze data, draw conclusions, and present results, which can ultimately improve higher-level thinking skills (Higher Order Thinking Skills/HOTS) such as analysis, evaluation, and creativity. A study by Wulandari et al. (2016) shows that the Learning Cycle 7e model significantly improves students' critical thinking skills and science processes through structured and repetitive learning stages. In addition, research by Jannah et al. (2024) shows that the application of the Guided Inquiry can significantly improve students' science literacy and data analysis skills.

The PBL model and Group Investigation provide significant opportunities for students to collaborate,

which enhances not only academic ability, but also social skills such as communication, leadership, and responsibility. In addition, the PBL-based Blended Learning model also incorporates digital technology in the learning process, which has been shown to be effective in improving students' learning motivation as well as critical thinking skills according to the report (Pratiwi et al., 2019).

The fundamental similarity of all these models is their contribution to improving science literacy, namely the ability to understand scientific concepts, interpret data, apply knowledge in everyday life, and make evidence-based decisions that are crucial to facing the challenges of the 21st century. Therefore, the use of a learning model based on constructivism is an appropriate and efficient method to build learning.

Learning Models That Impact Science Literacy by Region

Based on the results of the analysis of nine articles, 7 articles for the western part of Indonesia and 2 articles for the eastern part of Indonesia were found. The results of the study are explained in the figure below.

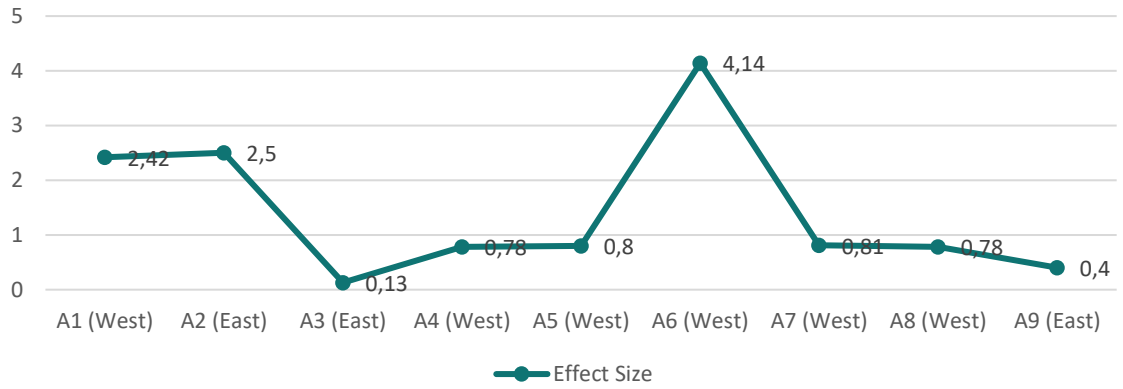

Figure 3. Effect Size Results by Region

Based on the table above, it shows the value of effect sizes that vary in various regions in Indonesia. The effect size value in western Indonesia varies as in western Indonesia, the effect size value is 1.51. This value is classified as high while in eastern Indonesia there is an effect size value of 1.64. Thus, science literacy abilities vary based on geographical location. The larger effect size in eastern Indonesia shows that the application of the learning model in this area has a greater impact on improving students' science literacy.

There are a few main reasons why this can happen. First, students in the eastern region typically have lower levels of science literacy compared to students in the western region. Learning models such as Learning Cycle 7e and an independent inquiry can help in this regard. This statement is supported by research from Setianingsih (2019), found that the application of the model Learning Cycle 7e Effectively improve students' science literacy as it encourages them to actively participate in the learning process.

Learning Models That Impact Science Literacy Based on Education Level

Based on the results of the analysis of nine articles, 5 articles for the high school education level and 4 articles for the junior high school education level were found. The results of the study are described below.

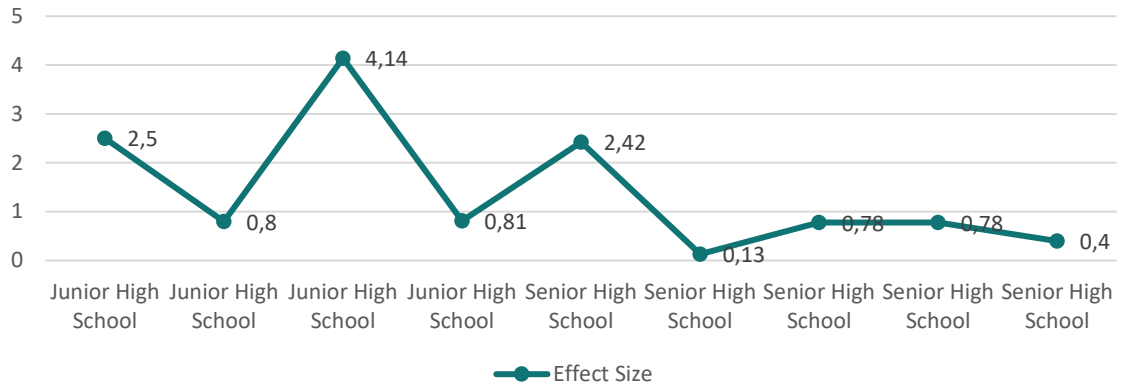

Figure 4. Effect Size Results Based on Education Level

Based on the data that can be seen, the application of the learning model to improve science literacy has a significant effect on both levels of education. The average effect size value for the junior high school education level is 2.06, which is in the high category. This shows that the learning model applied has a huge impact on improving the science literacy skills of junior high school students. Thus, the application of the right learning model has been proven to be able to have a greater impact both in junior high and high school, because at the high school education level, the average effect size value is also quite high, which is 0.90. Although this score is slightly lower than junior high school, this score shows that the learning model used is very effective in improving science literacy at the high school level.

Average score effect size junior high school students are higher than high school students because junior high school students are in the early phase of science literacy development, so the application of active and innovative learning models has a more significant impact. Junior high school students usually show greater enthusiasm for exploratory learning activities such as experiments and group discussions, so that their learning outcomes are more significant (Agustin et al., 2021). Meanwhile, high school students already have a stronger initial understanding, so the influence of the learning model tends to be more balanced. This shows that the learning model is more effectively applied at an earlier level.

Learning Models That Have an Impact on Science Literacy Based on Learning Materials

Based on the data displayed on the effect size results table, it is explained that the application of the learning model to improve science literacy has a significant impact on the learning meter learned. The effect size value for the interaction material of living things is 4.14, which is classified as high. This indicates that the learning approach used and the content taught have a significant influence on improving the science literacy skills of junior high school students. Therefore, the use of appropriate learning models has been proven to produce a more significant impact in both junior and senior high schools, because at the high school level, the value of the measurement effect is also quite large, namely 2.42 for global warming materials. Although this score is slightly lower than junior high school, it shows that the teaching method applied is very successful in improving science literacy at the high school level.

Living Creature Interaction material plays an important role in improving science literacy at the junior high school level because this topic is relevant to students' daily lives and encourages their understanding of the relationship between organisms and their effects on

the environment. Learning this material allows junior high school students to improve their observation, reasoning, and decision-making skills based on scientific evidence, which is the essence of science literacy. Material on the interaction of living things and the environment, such as predation, symbiosis, and biological control. For example, research conducted by Pujiasih et al. (2020), indicated that the Discovery Learning model for this material increased the N-gain score of science literacy content aspects from 0.21 (control class) to 0.38 (experimental class), and process aspects from 0.24 to 0.40. Research shows that the science literacy of junior high school students increases significantly when the interaction material of living beings is presented in a structured and interactive manner, as well as practicing scientific skills such as reading graphs, analyzing data, and making inferences. The improvements are most noticeable in conceptual understanding, critical thinking, and scientific processes.

Climate change materials are particularly relevant to improving science literacy at the high school level because they cover scientific concepts such as the effects of greenhouse gases, increased carbon dioxide emissions, and their impact on the global climate. High school students, who are already able to think abstractly, can be involved in temperature data analysis, interpretation of emissions graphs, and evaluation of scientific solutions to the climate crisis. This material not only deepens conceptual understanding, but also encourages students to think critically and make evidence-based decisions. Research by Nadia Laila Sari (2024) shows that although high school students' understanding of the greenhouse effect is still limited, this topic is important as an indicator of their concern for global issues.

CONCLUSIONS AND SUGGESTIONS

The results showed that the most effective learning model in improving science literacy was Discovery Learning, with the highest effect size value of 4.14. This model encourages students to be active in finding ideas, processing data, and concluding independently, so that it is relevant to be applied in the classroom. Overall, the learning model has a significant effect on improving science literacy, with high effect sizes recorded in various regions (1.51 in the west and 1.64 in the east), education level (2.06 in junior high school and 0.90 in high school), and materials such as interaction between living beings. Learning models that have proven to be effective include Discovery Learning, Free Inquiry, Problem Based Learning, Guided Inquiry, Blended PBL, Learning Cycle 7E, and Group Investigation.

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