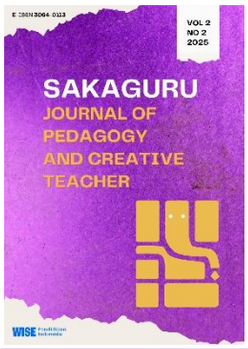

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Research Article

The Influence of Learning Cycle 9E Viewed from Computational Thinking Theory to Scientific Literacy Skills, Critical Thinking Skills, and Creativity

Toni Efriyandika[1*]; Resna Hegi Putra[1]; Yuni Pantiwati[2]; Iin Hindun[2]; and Abdulkadir Rahardjtano[3]

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Abstract

The main challenge in biology learning lies in students' low levels of scientific literacy, critical thinking, and creativity, often caused by teacher-centered practices that limit exploration and reflection. This study investigates the effect of the 9E Learning Cycle model integrated with Computational Thinking (CT) on improving students' scientific literacy, critical thinking, and creativity. A quasi-experimental design was used with three groups—experimental, positive control, and negative control—at MAN 1 West Lampung. Data were collected through pretests, posttests, and observations, analyzed using N-Gain and t-tests. The results show significant improvement in the experimental class, with science literacy increasing from 42% to 87% (N-Gain = 0.78, high category), critical thinking from 55% to 77%, and creativity from 51% to 79%. These findings indicate that the 9E Learning Cycle effectively enhances conceptual understanding, analytical reasoning, and creative problem-solving. The study concludes that integrating computational thinking within the 9E framework promotes 21st-century skills and supports the achievement of sustainable quality education in science learning.

Keywords: 9E Learning Cycle; Computational Thinking; Creativity; Critical Thinking; Scientific Literacy

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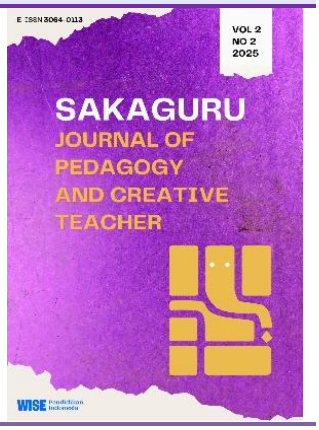

INTRODUCTION

Scientific literacy in knowledge biology refers to the ability to understand scientific concepts , processes, and principles related to biology . Scientific understanding is not just knowledge proportional but involving greater understanding in about phenomenon [1]. Scientific literacy very important for students in biology Because equip students with the skills necessary to understand and engage with scientific concepts , which are essential for addressing challenge contemporary [2]. Studies show that many biology students own low levels of scientific literacy , with average scores often falling below the threshold acceptable limits . This deficiency can hinder their ability to identify valid arguments , evaluating information , and apply skills quantitative in a way effective [3]. To improve scientific literacy , an educational framework that combines learning active , collaborative discussion , and learning contextual recommended [3]. Scientific literacy in students is expected to be able to evaluate scientific information , checking evidence , and take decision based on data. This is important in biology , many complex phenomena require critical and analytical thinking [4]. Students learn to use scientific methods to solve biological problems .

Critical thinking plays a pivotal role in biology education as it enables students to analyze complex concepts and construct deeper scientific understanding. Its integration into the biology curriculum is commonly achieved through inquiry-based learning and open questioning, which promote evidence-based reasoning and intellectual honesty [5]. Studies have shown a strong correlation between critical thinking skills and academic performance, with high effect sizes confirming its significant impact on learning outcomes [6]. Well-structured assessments have also proven effective in measuring analytical and creative thinking abilities in biology [7]. Moreover, critical thinking fosters innovation in interpreting biological phenomena [8]. Empirical research indicates that learning cycle models significantly enhance students' critical thinking—experimental groups achieving average scores of 90.36% compared to 68.81% in control groups [9], although contrasting results were found by Apryani & Suyanto (2021), who reported improvement through problem-based learning after three instructional cycles [10].

Creative thinking is essential in biology education as it fosters innovation, logical reasoning, and problem-solving abilities among students [11]. Recent studies emphasize that interactive and inquiry-based learning approaches effectively enhance creativity by actively engaging learners in constructing biological concepts [12]. The integration of virtual technologies, such as simulations, virtual reality, and augmented reality, further supports the visualization of complex biological processes, thereby improving engagement and creative expression [6]. Project-based laboratory activities have also been shown to significantly strengthen students' creative dispositions compared to traditional methods [13]. Empirical evidence demonstrates that learning cycle models produce higher creative thinking outcomes, with an average score of 89.56%, compared to 81.7% achieved through problem-based learning [14], [15]. This superiority is attributed to the structured and coherent stages of the learning cycle, which provide greater opportunities for exploration, reflection, and creative synthesis.

Recently , scientific literacy experience decline , causes low scientific literacy namely the existence of a learning process that does not support student in developing scientific literacy skills [16]. This was proven through the PISA test conducted by the OECD , namely Indonesia's final average score was 396 and ranked ranked 71 out of 79 participants [17]. This low result indicates that that the learning process Not yet notice scientific literacy skills in students [18].

This is in line with research that has been carried out which states that low scientific literacy skills influenced by the learning process at school.

February 18, 2024, the learning process that took place Not yet train students in understand literacy context , critical thinking skills and student creativity. This is due to there is no interaction with each other. In fact, interaction between friends peers in argumentation and discussion are capable help explain logical thinking. This is in line with research which states that the interaction between students in the learning process it is very important to build something information [19]. In addition, researchers have also provided test initial scientific literacy skills in students as many as 10 questions and the average score obtained by 45% with the number of student samples as many as 32, this shows that scientific literacy skills student still low.

Low scientific literacy significant impact on critical and creative thinking skills among students [20]. Research shows that the lack of scientific literacy hinder students' ability to analyze problems, evaluate information, and generate innovative solutions. This deficiency can lead to decline critical thinking skills. Low scientific literacy limits students' ability to identify and clarify scientific problems, which is essential for critical thinking [21]. Students with inadequate scientific literacy often fail to engage in stages necessary problem solving, such as judgment and conclusion [22]. Studies show that scientific literacy improves communication skills, which are essential for creative thinking [23]. The relationship between scientific literacy and creative thinking is evident , as both skills support ability to build scientific explanation and innovation.

Low scientific literacy and critical thinking in schools stems from from various interrelated factors, including inadequate teaching resources, untrained educators, and a lack of engaging learning experiences [24]. Inadequate Educational Resources many textbooks science is outdated or poorly designed. Opportunity development professional development for teachers is often insufficient, leading to a cycle of practice ineffective teaching. Engagement and learning strategies implementing inquiry-based learning and literacy strategies, such as organizers graphic has proven to increase students' understanding and confidence in science [25]. Active learning experiences related to interests students can significantly improve critical thinking and scientific literacy [26].

Science learning is inseparable from the essence of science, which encompasses science as a process, an attitude, a product, and its technological applications [27]. Research on science process skills shows that the learning cycle model effectively enhances students' ability to engage in scientific inquiry, supporting previous findings that the essence of science forms the foundation of scientific literacy [28] [29]. Rooted in constructivist theory, the learning cycle positions teaching not as the transmission of knowledge but as a process of reconstructing and building new ideas [30]. Developed from Piaget's theory, it emphasizes the role of physical experiences and environmental interaction in promoting cognitive development [31]. This study is novel because it integrates the 9E Learning Cycle with Computational Thinking (CT), forming a unified pedagogical framework that connects inquiry-based exploration with algorithmic reasoning, an approach not yet systematically examined in science education research.

Therefore, this study aims to investigate the effect of the 9E Learning Cycle integrated with Computational Thinking (CT) on students' scientific literacy, critical thinking, and

creativity in biology learning. Specifically, it seeks to determine how this integrative model enhances higher-order thinking skills compared to conventional approaches and to identify its potential contributions to innovative science pedagogy. This research has contribution in effort helps improve science literacy skills, critical thinking skills , and creativity of students at MAN 1 West Lampung. Previous research only research scientific literacy level students only reached the *7E stage* and researched at the Junior High School (SMP) level [32]. This research used the *9e learning cycle* model which consists of of the 9 stages that will be reviewed the correlation from *computational thinking theory* [33].

METHODS

Research Design

The type of research is quantitative research using the quasi-experimental method. *Quasi-experimental* has two classes, namely the experimental and control classes. The study used a *pretest and posttest group* design. This design has two groups that were previously selected randomly , namely the experimental group and the control group. Furthermore, the experimental class and the control class will be given a pretest at the beginning. learning and given post-test at the end learning.

Population and Sample

The population of this study comprised Grade XI science students from MAN 1 West Lampung, Indonesia, during the 2024/2025 academic year. Three classes, each consisting of 30 students, participated in the study: Class XI IPA 1, XI IPA 2, and XI IPA 3. Using a purposive sampling technique, the classes were selected based on differences in prior academic achievement. Class XI IPA 1 served as the experimental group taught using the 9E Learning Cycle integrated with Computational Thinking (CT), Class XI IPA 2 as the positive control group taught with the standard 9E model, and Class XI IPA 3 as the negative control group taught conventionally. Participants aged 16–17 years represented a balanced gender distribution and had comparable academic backgrounds in biology, ensuring uniform readiness for the intervention.

Location and Timing

The research was conducted at MAN 1 West Lampung in grades XI IPA 1, XI IPA 2, and XI IPA 3 in the even semester of the 2023/2024 academic year, with the research period starting from December 2023 to May 2024. The research was conducted at MAN 1 West Lampung in grades XI IPA 1, XI IPA 2, and XI IPA 3 in the even semester of the 2023/2024 academic year, with the research period starting from December 2023 to May 2024.

Research Procedures and Instruments

The research consisted of two stages: preparation and implementation. In the preparation stage, biology teaching modules on the human reproductive system were developed, and research instruments, comprising a scientific literacy test and observation sheets for critical thinking and creativity, were validated by experts for content and reliability. The tests measured

students' skills in data interpretation, reasoning, analysis, inference, and creative problem solving. During the implementation stage, students in each class completed a pretest, received instruction through their respective learning models (9E with CT integration, standard 9E, and conventional), and then took a posttest and were observed to assess improvements in scientific literacy, critical thinking, and creativity.

Data Analysis Techniques

Research data that has been obtained will analyzed using the help of the SPSS application version 25 and Microsoft Excel 2019. The data analyzed namely test result data scientific literacy, creativity, and critical thinking skills. Then research data analysis was carried out comprehensive namely normality test, homogeneity test and research hypothesis test.

RESULTS AND DISCUSSIONS

Result

Descriptive data analysis about *learning cycle 9e* in the learning process presented in Figure 1. The learning process by integrating 9E activities provides good results when viewed from the data presented in Figure 1. The projects carried out by students in several activities are still need direction and guidance during the learning process. Students are still less critical in investigate and analyze the data needed to complete something project, therefore it must be emphasized in a way Repeatedly. Furthermore, various activities and repeated emphasis can improve students ' scientific literacy skills. They can also work together and collaborate with their groups, so that the results of the analysis made during several activities can produce expected product. To get used to it do exploration through learning investigation, organizing problems, organizing data, making hypotheses, then it is necessary to increase reflection during project activities. The results of this research include several components namely the test results scientific literacy skills, critical thinking skills and student creativity.

a. Experimental Class Science Literacy Test

Test results diagram scientific literacy skills of students in the experimental class consisting of of 31 student samples are presented in **Figure 1** below.

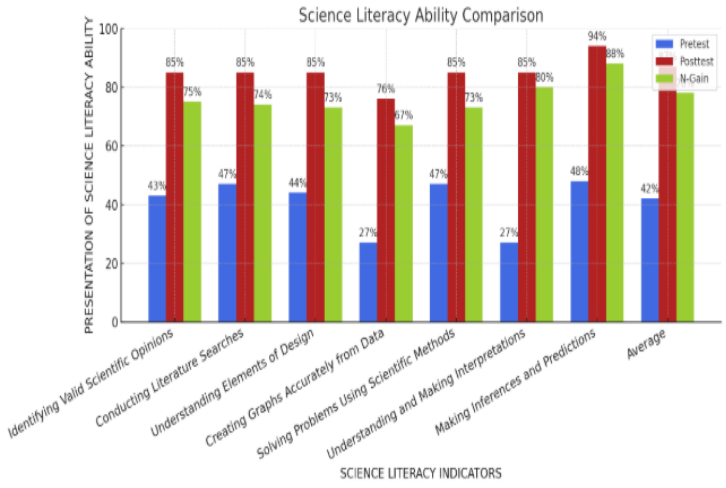

Figure 1. Diagram of Scientific Literacy Skills of Experimental Class Students

The results indicate a significant improvement in students' scientific literacy following the intervention. The overall average increased from 42% on the pretest to 87% on the posttest, yielding a high N-Gain score of 0.78. The most notable progress occurred in higher-order indicators such as inference and prediction, which achieved posttest scores above 90%. Meanwhile, the ability to interpret and explain scientific information also showed substantial gains. In contrast, the skill of accurately constructing graphs recorded the lowest improvement, suggesting the need for more focused practice in data visualization. Overall, the 9E Learning Cycle integrated with Computational Thinking (CT) effectively enhanced both conceptual understanding and analytical reasoning, demonstrating strong potential for developing students' scientific literacy and higher-order thinking skills.

b. Positive Control Class Science Literacy Test

Test results diagram scientific literacy skills of students in the positive control class consisting of of 30 student samples are presented in **Figure 2.**

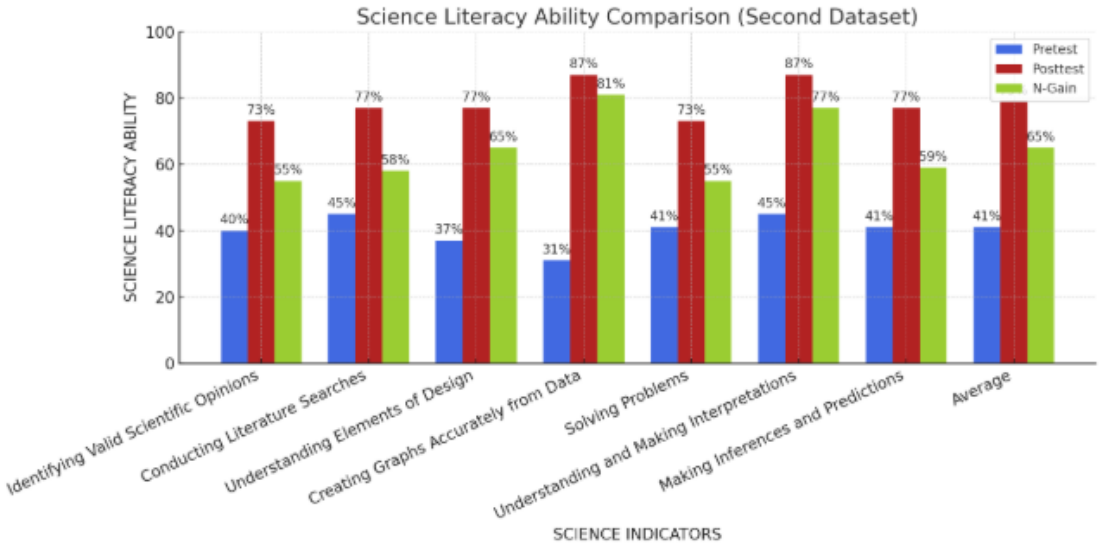

Figure 2. Diagram of Science Literacy Skills of Positive Control Class

It can be explained in diagram 2 that mark pretest ability with an initial average of 41% has increase in value ability posttest with a final average of 79% with an n-gain value of 64% which is included in the moderate category. gain value. Based on the *output* results referring to Hake,R .R that is category The N-gain in the form of a percentage of the interval below 30% is low, the interval from 31-70% is medium, and the interval above 70% is high. The results show that *the 9e learning cycle* model is better. Superior because each stage learning will make students more actively involved in the process and there is the use of technology at the end learning that is in line with the essence science and supported by *computational thinking theory*.

c. Negative Control Class Science Literacy Test

The scientific literacy skills of the negative control class using a sample of 32 students are presented in **Figure 3** below.

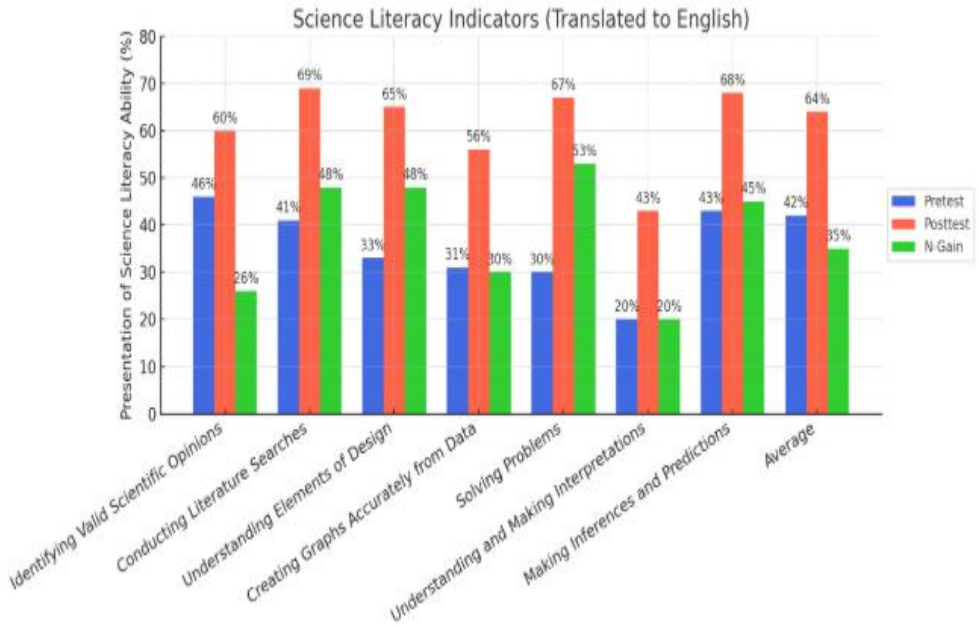

Figure 3. Diagram of Science Literacy Ability of Negative Control Class

In the negative control class, students' scientific literacy scores showed only modest improvement, rising from an average pretest score of 42% to a posttest score of 64%, corresponding to an N-Gain of 0.36, categorized as low according to Hake's criteria. This outcome contrasts sharply with the experimental and positive control classes, which achieved substantially higher gains through the 9E and CT-integrated learning approaches. The findings suggest that the direct instruction model applied in the negative control class was less effective in fostering scientific literacy, as reflected in the considerably lower posttest results and limited progression in higher-order thinking indicators.

d. Critical Thinking Skills

The diagram of students' critical thinking skills is presented in Figure **4** below.

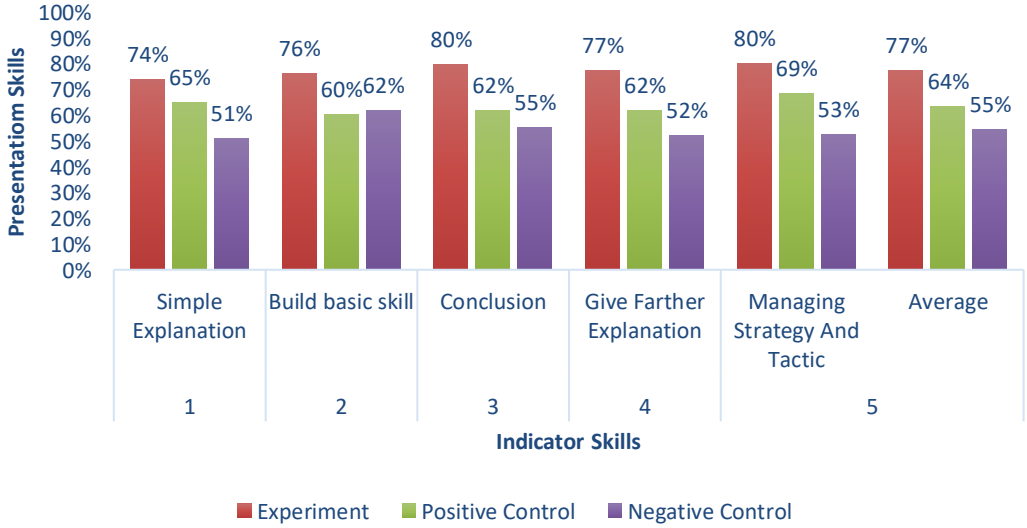

Figure 4. Skill Diagram *Critical Thinking*

Based on the diagram of the 4 skills The critical thinking of students in the experimental class resulted in an average observation of 77%. In the positive control class, the average observation was 64%. In the negative control class, the average observation was 55%. Based on the results of the sheet related observations skills critical thinking more experimental class students own The positive impact of implementing the 9e learning cycle model compared to the positive control class that implemented the problem-based learning model and the negative control class with the direct instruction model. The negative control class had a lack of student engagement. student information only teacher-centered, so that students have less opportunity to participate active in learning. This can reduce motivation and interest students, especially those who learn better through exploration or collaboration.

e. Creativity Skills

As for creativity skills students are presented in Figure 5 below.

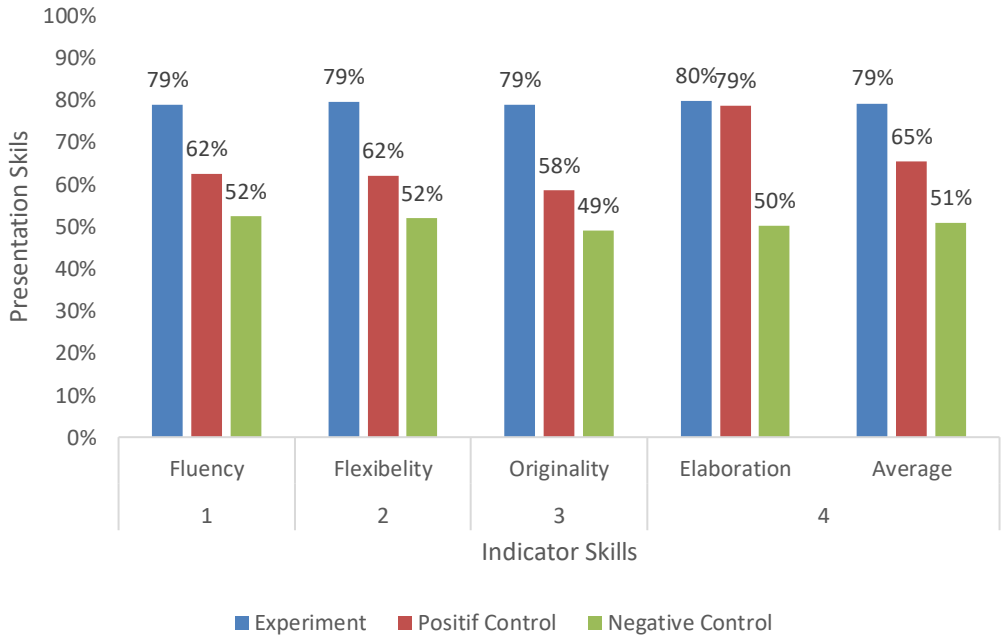

Figure 5. Skill Diagram *Creativity*

Based on the diagram of the 5 creative abilities Students in the experimental class produced an average observation of 79%. In the positive control class, the average observation was 65%. In the negative control class, the average observation was 51%. Based on the results of the observation sheet related to skills *creativity* of students in the experimental class is greater own achievements more indicators purple; by applying the *9e learning cycle* model when compared with the positive control class that applies the *problem- based learning* model and the negative control class with the *direct instruction model.* Descriptive analysis related to the influence of the 93 learning cycle model on scientific literacy skills , critical thinking skills and creativity of students as well shown in Table 1, Table 2, Table 4, and Table 4 below.

f. Normality Test

The results of *the output* of the normality test for the science literacy test There is presented in **Table 1** below.

Table 1. Normality Test Science Literacy

	Class	*Kolmogorov Smirnov*			*Sapiro-Wilk*		
		Statistics	***Df***	***Probability***	***Statistics***	***df***	***Probability***
Science Literacy	Experiment	.150	31	.074	.958	31	.253
	Positive Control	.147	30	.097	.948	30	.154
	Negative Control	.124	32	.200	.979	32	.779
Skills Thinking Critical	Experiment	.091	31	.200	.981	31	.851
	Positive Control	1.69	30	.029	.954	30	.213
	Negative Control	.132	32	.172	.975	32	.537
Creativity Skills	*Experiment*	*.122*	*31*	*.200*	*.974*	*31*	*.632*
	Positive Control	1.46	30	.103	.928	30	.332
	Negative Control	.172	32	.016	.954	32	.192

The Kolmogorov–Smirnov normality test results showed that all data were normally distributed, as indicated by Asymp. Sig. (two-tailed) values greater than 0.05 across all groups and variables. Specifically, for scientific literacy, the experimental, positive control, and negative control classes recorded Asymp. Sig. values of 0.74, 0.97, and 0.20, respectively. For critical thinking, the respective values were 0.20, 0.79, and 0.17, while for creativity, the values were 0.20, 0.10, and 0.16. Since all significance values exceeded the 0.05 threshold, the data for each variable met the assumption of normality and were therefore suitable for subsequent parametric statistical analysis.

g. Homogeneity Test

The results of the homogeneity test can be presented in **Table 2** below.

Table 2. Homoegeneity Test

Box'M	115,459
Probability	.110

Based on *output* table 2 is known that mark *Sig (5-tailed)* of 0.110 with a value of box'm 115.459 is greater than 0.05. So it is in line with the basis of taking decision with the decision taken is H_0 accepted , then a *homogeneity of variances* test can be carried out.

Table 3. Homogeneity of Var

Variables	***Df1***	***Df2***	***Probability***
Science Literacy	2	90	.765
Critical Thinking	2	90	.300
Creativity	2	90	.210

Based on *output* table 3 is obtained mark significance scientific literacy skills of 0.765 and significance observation sheet of 0.765, if the conditions sig value > α 0.05 then show that the data is homogeneous and there is the influence between scientific literacy skills (Y1) and 4C skills (Y2) against X. After conducting the prerequisite test normality and homogeneity can be used to test the hypothesis.

h. Hypothesis Testing

The hypothesis in this study uses the *T Sample Test* analysis which is presented in Table 4 below.

Table 4. Normality Test Science Literacy

	T	Df	Sig 5 Tailed	Mean Difference	Lower	Upper
Science Literacy	41,222	92	.000	42.15054	40.1197	44.1814
Critical Thinking	50,298	92	.000	22.10753	21.2346	22.9805
Creativity	42,032	92	.000	24.66667	23.5011	25.8322

Based on table 4, the t-sample t-test explain that test comparisons are taken from the average of the components of scientific literacy and 4C skills with treatment (experiment, positive control, and negative control). The results of the treatment get sig. value 0.00 then according to the criteria that H_1 (accept).

Learning cycle model in a way extensive in various context proven to improve scientific literacy. Research has show that implementing *the learning cycle* model have a positive impact on student activity levels and learning outcomes science, which leads to improvement involvement and improvement of student learning outcomes [5]. In addition, integration Technology Information and Communication Technology (ICT) into the *learning cycle* model has found to improve digital literacy among students, make learning more effective and meaningful in the era of revolution Industry 4.0 [34]. Comparative analysis from the cycle model different learning, such as 3E, 5E, 7E, and 9E, have been highlight the importance of developing understanding conceptual, process skills, and critical thinking through the cycle well-structured learning [35]. Empirical studies have show that inquiry-based instruction integrated, such as the approach *learning cycle* have a positive impact on students' cognitive development, emotions, engagement, and academic self-concept, especially in arrangement education science. In Overall, the application of *the Science Learning Cycle* (SLC) model has been proven in a way significantly improve scientific literacy and understanding conceptual among students in vocational schools medium, emphasizing effectiveness this approach in improving learning outcomes in education biology [14].

Learning cycle 9E is a teaching model that aims to improve science process skills. students through learning, as proven by research studies by implementing the *9e learning cycle* model at home via an online platform , there is an increase significant in science process skills student observed , with an average N-Gain of 84% and higher achievement tall in indicators such as communication and prediction [35]. This model, together with the cycle learning others such as 5E, emphasize development understanding conceptual skills, process skills, and critical thinking, contribute to effective inquiry-based learning experiences [9]. In addition, the effectiveness of instructional materials based on cycle 9E learning is demonstrated in

improving students ' self -efficacy and learning outcomes in eye lessons such as acid-base problems , show benefit practical from approach [36].

9E learning cycle provides positive impact on Students' 4C skills (Critical Thinking, Creativity, Collaboration , *and Communication).* Through structured stages In the 9E model, students are actively involved in the learning process, encourage them to think critically, collaborate with their friends , communicate in a way effective , and develop their creativity in solve the problem [37]. Viewed in Critical Thinking aspect, learning cycle encourages students to analyze information, evaluate arguments, and solve problems in a systematic. Students invited to ask questions and discuss concept , which sharpens their critical thinking skills. Students are given the opportunity to explore new ideas and create innovative solutions. Challenging projects and assignments push students to think outside the box conventional and develop creativity [38]. The learning cycle often involves group activities that allow students work together, share ideas, and support each other. This collaboration helps students learn to appreciate other people's perspectives and improve skills Work in Student team trained to communicate their ideas clearly and effectively, both orally and oral and written [30]. Group discussions and presentations help hone their communication skills, which are very important in various aspect life.

The influence *of learning cycle 9e* on scientific literacy skills very positive. It helps students more understand scientific concepts through a structured and repetitive approach, so that strengthen their knowledge in general In-depth. With clear stages, such as *engagement, exploration, explanation, elaboration, and evaluation,* students are encouraged to actively participate in the learning process. The result is improved scientific literacy skills. student increase in a way substantial. They become more skilled in analyze information, developing arguments based on scientific evidence, and solve complex problems in a more effective and efficient. This is reinforced by research by [39] which states that with *the learning cycle,* students not only get knowledge theoretical but also develop critical, analytical and creative thinking skills . In line with research by [40], the results of which showed that scientific literacy skills student increase in a way substantial, they are more capable understand scientific concepts , applying knowledge in real situation.

Research shows that *the 9e learning cycle* model contribute to development students' critical thinking skills and scientific literacy in context student knowledge [41]. Implementing the *9e learning cycle* model at home through learning *on line* has proven to improve science process skills student in a way significant , with a high average N-Gain percentage , especially in indicators such as communication and conclusions [35]. Learning cycle 9e provides a comprehensive framework to promote scientific literacy and independence in learning , which leads to understanding better conceptualization and improvement skills scientific reasoning [8]. Learning cycle model 9e integrate critical thinking skills in collaborative activities . In the Exchange and Evaluation stage, students Work in groups to analyze problems, discuss solutions, and provide criticism constructive, which strengthens critical thinking skills. Next, the 9e learning cycle model has influential to critical thinking skills of junior high school students in education science, emphasizing the importance of effective teaching models in grow critical thinking skills among students [42]. This finding is generally collective highlight effectiveness various cycle models learning, including LTM 9E, in maintain and improve students' critical thinking skills in various fields level education and eyes lessons . The results

of the study stated that application of the learning cycle 9e model has show significant impact on students' critical thinking skills in various arrangement education [43]. In line with studies that have done show that learning cycle 9e positively influence ability student in analysis, inference, and critical thinking overall [44].

The influence of the 9e learning cycle to skills critical thinking very positive and profound. Research results [6] explain that students are involved in an active and reflective learning process, through stages such as exploration, elaboration, and evaluation. In each stage, students are encouraged to submit questions, formulate hypotheses, and search and analyze information critically. This process helps Students develop essential critical thinking skills, such as the ability to evaluate arguments, identifying assumptions, and make decision based on proof.

Studies that have been conducted show effectiveness of the cycle model 9e learning in improving creative thinking skills through activities that promote fluency, flexibility, originality, and elaboration [33]. In addition, research by Küçük & İşleyen highlight positive effects of learning argumentation-based science on students' creative thinking abilities. This is reinforced by research collective show that apply cycle learning such as 9E can be significantly improve students' creativity skills by involving them in learning collaborative, hypothesis development, problem solving, and experimental activities, which ultimately prepare them for the demands of public 21st century [44] [46].

CONCLUSION

This study demonstrates that integrating the 9E Learning Cycle with Computational Thinking (CT) significantly enhances students' scientific literacy, critical thinking, and creativity. The systematic phases of the 9E model, emphasizing exploration, elaboration, and evaluation, fostered inquiry, analytical reasoning, and creative problem solving, surpassing the outcomes of both the conventional 9E and direct instruction models. Theoretically, this research contributes to science education by bridging constructivist pedagogy with computational reasoning, offering a framework for developing higher-order thinking in digital-era classrooms. Practically, the findings suggest that teachers and curriculum designers should adopt integrative, reflective, and data-driven strategies to cultivate twenty-first-century competencies in biology learning. However, the study was limited to a single school context and short-term implementation, restricting generalization across broader populations. Future research should extend this model to diverse educational settings, employ longitudinal designs, and explore how teacher readiness and technological infrastructure influence the sustainability of 9E-CT integration.

LIMITATIONS

Although the study provides valuable insights into the effectiveness of the 9E Learning Cycle model integrated with Computational Thinking in enhancing students' scientific literacy, critical thinking, and creativity, several limitations should be acknowledged. First, the research was conducted with a relatively small and localized sample drawn from a single institution (MAN 1 West Lampung), which may limit the generalizability of the findings to broader educational contexts. Second, the study's quasi-experimental design did not fully control for

external factors such as teacher variability, student motivation, or prior conceptual understanding, which may have influenced the outcomes. Third, the assessment instruments focused primarily on cognitive indicators, leaving affective and behavioral dimensions underexplored. Finally, the short duration of the intervention prevented the observation of long-term retention and transfer effects. Future research should employ longitudinal or mixed-method approaches across multiple schools and regions to validate and expand upon these findings.

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CONFLICT OF INTEREST

"The authors declare no conflict of interest."

DECLARATION OF USE OF AI IN SCIENTIFIC WRITING

The author used Artificial Intelligence (AI) tools, including ChatGPT developed by OpenAI, were utilized in this study solely to assist in language editing, grammar refinement, and formatting adjustments in accordance with international academic writing standards.

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