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SM2CL Model Innovation: Biology Learning Strategy to Sharpen Students' Critical Thinking

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ABSTRACT

Purpose of the study: This study aims to analyze the influence of the Synectics, Mind Maps, and Cooperative Learning (SM2CL) learning models on students' critical thinking skills in biology subjects.

Methodology: This study is a quasi-experimental study with a pretest-posttest control group design. The sampling technique used was total sampling with 47 students as samples. The research instruments consisted of essay tests and critical thinking scale questionnaires. Data were analyzed using descriptive and inferential statistics with normality tests, homogeneity tests, and t-tests using SPSS software version 24.

Main Findings: The Synectics, Mind Maps, and Cooperative Learning (SM2CL) learning model significantly improves students' critical thinking skills. The t-test results showed a significant difference between the experimental class and the control class, with a higher increase in post-test scores in the experimental class. The analysis data showed that the SM2CL model was effective in improving students' conceptual understanding and critical thinking skills in Biology subjects.

Novelty/Originality of this study: This study combines three learning models Synectics, Mind Maps, and Cooperative Learning (SM2CL), as an innovative approach to improve students' critical thinking in Biology. This study expands the understanding of the effectiveness of collaborative and visual methods in learning, and provides new insights into the application of integrated learning strategies in improving the quality of education.

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1. INTRODUCTION

In this modern era, globalization has facilitated the fulfillment of human needs, such as access to information, transactions, and both national and international economic cooperation. Moreover, it has contributed significantly to the advancement of science, particularly in the field of education [1]-[3]. These developments demand individuals to be more critical and adaptive, especially in responding to educational challenges in Indonesia, such as those posed by the ASEAN Economic Community (AEC) [4]-[6]. The AEC calls for a workforce that is competent, competitive, and mentally prepared to face future uncertainties [7], [8]. Consequently, education must not only focus on academic achievement but also aim to develop students' critical thinking skills [9], [10], which are essential for the younger generation to thrive in an increasingly complex global society.

In response to these demands, the Indonesian education landscape must also adapt to the challenges of the knowledge era, characterized by rapid technological development and unpredictability. Handy refers to this as the era of intellectual capital, where education must prioritize the development of students' intellectual capabilities to remain relevant [11], [12]. Therefore, the education system should emphasize enhancing students' thinking skills rather than merely transferring factual knowledge [13], [14]. This calls for teachers and educators to innovate learning methods that foster critical thinking patterns [15], [16]. Without such innovation, students risk becoming passive recipients of information, unable to process knowledge independently [17], [18]. Thus, the core objective of learning should be to nurture students' capacity to think critically and creatively in order to face global challenges effectively.

Education, at its core, is an interactive process between educators and learners, where mutual influence occurs. Teachers serve as facilitators who help students unlock their potential and sharpen their cognitive abilities [19], [20]. In addition to educators, families also play a crucial role in shaping children's character and mindset from an early age. As the first environment where children learn, the family lays the foundation for formal education [21], [22]. Therefore, parental involvement has a significant impact on students' academic and personal success. Quality education is not solely the responsibility of formal institutions but also depends on strong family support in creating a conducive learning environment [23], [24].

To achieve meaningful education, critical thinking skills must be instilled from an early age, especially in the school setting. Students should not only aim to complete tasks or earn high grades, but also learn to analyze information, evaluate its validity, and make sound decisions [25], [26]. Without these skills, they may struggle to grasp complex concepts or navigate the flood of misinformation in the modern world [27], [28]. Critical thinking plays a vital role in both personal and social problem-solving [29], [30]. Students equipped with such skills are better prepared to meet the demands of the global era, where independent and analytical thinking is indispensable [31], [32]. Therefore, effective learning should prioritize the development of critical thinking to prepare students for real-world challenges.

From a neurological perspective, the human brain consists of two hemispheres with distinct functions: the left brain handles linear, logical thinking, while the right brain supports creativity and holistic understanding. However, current educational practices often emphasize left-brain activities, which may cause students to rely heavily on memorization and repetition, rather than independent understanding. This imbalance can hinder creativity and limit meaningful learning experiences [33], [34]. In fact, the human brain is naturally designed to think in a radiant pattern—one that encourages the generation of new ideas from a central concept. Thus, learning methods that engage both hemispheres are essential for optimal intellectual development.

To address these limitations, learning models grounded in cognitive psychology—which place students at the center of learning—are increasingly necessary. Several studies have demonstrated that the SM2CL model—which integrates Synectics, Mind Maps, and Cooperative Learning—effectively enhances students' critical thinking skills and learning outcomes, especially in science learning contexts [35], [36]. These models promote active knowledge construction and encourage deeper engagement with content. One such approach is the eclectic method, which integrates multiple strategies, models, and techniques to improve learning effectiveness. By offering variety and flexibility in instruction, an eclectic approach supports the development of a broader range of cognitive skills, making learning more meaningful and better suited to address the complexities of the global era.

A promising example of this is the Synectics, Mind Maps, and Cooperative Learning (SM2CL) model. This model blends three core strategies: analogical thinking through synectics, conceptual visualization using mind maps, and collaborative problem-solving via cooperative learning. In addition to fostering creativity and collaboration, the SM2CL model has been empirically shown to significantly improve students' ability to analyze, evaluate, and understand biological concepts more deeply [37]. According to Buzan, mind mapping stimulates the brain's ability to connect and organize ideas, while cooperative learning fosters understanding through peer interaction and discussion. The integration of these elements encourages active student participation and strengthens critical thinking. As a result, students not only grasp lesson content more deeply but also become more engaged in their learning process.

Previous studies conducted by Tongal et al. [38] and Zhang et al. [39] have emphasized the importance of learning strategies such as metacognition and collaboration in improving critical thinking skills. However, only a few have comprehensively examined the integrated SM2CL model. In addition, most of these studies were conducted outside the Indonesian context, thus not fully reflecting the specific needs of Biology education in Madrasah Aliyah. Therefore, this study is important to fill this gap by investigating the effectiveness of the SM2CL model in the local educational context..

In light of the above considerations, the implementation of the SM2CL learning model is expected to support students in developing both creative and analytical thinking, particularly in Biology education. This model not only enhances students' comprehension of the subject matter but also builds their problem-solving skills and social competence through group collaboration. By combining various instructional techniques, students are better equipped to understand abstract or complex concepts and apply them in real-world contexts. Therefore, this study aims to analyze the implementation of the Synectics, Mind Maps, and Cooperative Learning (SM2CL) model and

its impact on the critical thinking skills of Grade XI students at Madrasah Aliyah Madani Alauddin Pao-Pao in Biology learning. The findings are expected to contribute to the development of more innovative and effective learning strategies in Indonesian education.

2. RESEARCH METHOD

This type of research is quasi-experimental research which involves a control group in addition to the experimental group, where the subjects are given treatment and then the effects of that treatment on the subjects are measured.

2.1 Research Design

This research design uses a pretest-posttest control group design, where the use of this research design is intended to reveal a causal relationship by involving a control group in addition to the experimental group. In this design, the experimental group is given treatment while the control group is not. In both groups, it begins with a pre-test, after the treatment is given, a re-measurement is carried out (post-test). The research design model can be seen in the table below:

Table 1. Pretest-Posttest Control Group Design

Subyek	Pretest	Treatment	Posttest
nR	O	X	O
nR	O	-	O

Information:

- nR = Not random
- X = Independent variable or treatment
- O = Observation (Measurement)

The research approach is an approach in the field of education, where the author tries to find out how much influence the synectics, mind maps, cooperative learning (SM2CL) learning model has on the critical thinking skills of class XI students of Madrasah Aliyah Madani Alauddin Pao-Pao in the biology subject with the material of the motor system.

2.2 Population and Research Sample

The population and sample in this study were all students of class XI Madrasah Aliyah Madani Alauddin Pao-Pao consisting of class XI.1 and class XI. 2 with a total number of 47 students. In this study, the researcher selected the research sample using the total sampling technique, so that the sample in this study amounted to 47 people.

2.3 Data Collection Methods and Research Instruments

The data collection method in this study was carried out using research instruments in the form of essay tests and critical thinking scale tests (pre-test and post-test). A test is a technique or method used in order to carry out measurement activities in which there are various questions or a series of tasks that must be done or answered by students to measure the abilities and behavioral aspects of students. To see students' critical thinking abilities, students are given tests in the form of essays (pre-test and post-test) and tests in the form of students' critical thinking scales that have been tested for validity by experts in the field. There are two instruments used in this study, namely the first in the form of an essay test (pre-test and post-test) which contains critical questions made based on indicators of critical thinking abilities according to Ennis which can be seen in Appendix B (research instrument).

The second instrument is a critical thinking attitude scale test made in the form of a questionnaire. This questionnaire contains critical statements to strengthen the results of the essay test given to students with the attitudes shown in the students, where the results can be seen in the questionnaire completed by the students themselves. This questionnaire was also created based on the critical thinking ability indicators according to Ennis which can be seen in table 2 of the research instrument, where the validity of this research instrument has been tested by experts in the field.

Table 2. Pre-test question grid and post-test question grid

Aspects	Indicator	No Item Questions		Question weight
		Pretest	Posttest	
Providing simple explanations	Focusing questions Analyzing questions Asking and answering questions about an explanation	1	4	25
Building basic skills	Considering whether the source is reliable or not Observing and considering a report of the results of an observation	2	3	20
Concluding	Deducing and considering the results of deduction Inducing and considering induction Making and determining the results of consideration	3	5	10
Providing further explanations	Defining terms and considering a definition in three dimensions Identifying assumptions	4	2	15
Setting strategies and tactics	Determining an Action Interact with other people	5	1	30
	Total			100

The grid for the critical thinking attitude scale instrument for students is presented in Table 3 below:

Table 3. Grid of thinking scale instrument

Aspects	Indicator	No Item Question	
		Positive	Negative
Providing simple explanations	Focusing questions	1	8
	Analyzing questions	3	10
	Asking and answering questions about an explanation	5,7	12,14
Building basic skills	Considering whether the source is reliable or not	9	16
	Observing and considering a report of the results of an observation	11	18
Concluding	Deducing and considering the results of deduction	13	20
	Inducing and considering induction	15	22
	Making and determining the results of consideration	17	24
Providing further explanations	Defining terms and considering a definition in three dimensions	19	26
	Identifying assumptions	21	28
Setting strategies and tactics	Determining an Action	23, 25	30, 2
	Interact with other people	27, 29	4, 6
	Total	15	15

2.4 Data Analysis Techniques

Based on the type of research in this paper, namely quantitative research, the researcher uses statistical data analysis techniques, namely descriptive statistics and inferential statistics. Inferential statistics are statistical techniques used to analyze sample data and the results are applied to the population. Inferential analysis is used to find out whether there is a significant increase in students' critical thinking skills with the material "motion system" in class XI Madrasah Aliyah Madani Alauddin Pao-Pao using the SM2CL model. The steps taken in analyzing this research data begin with conducting a data normality test to determine whether the data used is normally distributed or not.

The criteria for testing normality with SPSS version 24 processed results are if sig> $\alpha = 0.05$ then the data is normally distributed and if sig <$\alpha = 0.05$ then the data is not normally distributed [40], [41]. The homogeneity test is a test of the similarity of several parts of the sample, namely the uniformity of the variance of samples taken from the same population which aims to see whether the data in both groups come from a homogeneous or heterogeneous population. The homogeneity test is a requirement for conducting testing in inferential analysis [42].

The test criteria are if Fcount < Ftable significant level $\alpha = 0.05$, then the population has a homogeneous variance. The hypothesis test used is the t-test statistic with paired-samples t-test analysis. Paired-samples t-test analysis is used to study two variables in this study whether they have an influence/relationship or not [43]. In this study, only the Y variable has a value, which will later be analyzed using the paired-samples t-test. The decision-making criteria for this test are if the sig. or p-value <0.05 then there is a difference between before and after treatment [44], [45].

3. RESULTS AND DISCUSSION

This study uses the synectics, mind maps, cooperative learning (SM2CL) learning model to determine students' critical thinking skills by using a learning model that invites thinking in the Biology subject at Madrasah Aliyah Madani Alauddin Pao-pao. Data collection was carried out by observation and tests. The test instrument was in the form of essay questions and questionnaires (pre-test and post-test), where essay questions were used to test students' critical thinking skills containing critical questions and questionnaires containing critical statements were used to strengthen the essay test on students' critical thinking attitudes in each learning activity by applying the SM2CL learning model in the experimental class, in order to determine how much influence the SM2CL learning model has on students' critical thinking skills.

The data collected were analyzed using statistical data analysis techniques, namely descriptive statistics and inferential statistics with testing using the "t-test". Based on the results of the research that has been conducted on students of class XI.1 as an experimental class that was given treatment with a total of 24 students, and students of class XI.2 as a control with a total of 23 students at Madrasah Aliyah Madani Alauddin Pao-pao, data can be collected through tests that are done by the students themselves as respondents. The results of the pre-test and post-test of critical thinking skills of students of class XI. 1 and students of class XI.2 are as follows: The following are descriptive statistics of the results of the critical thinking ability test of students as an experimental class where the data is processed using SPSS version 24 as in the table below:

Table 4. Descriptive statistics of the results of the pretest and posttest of critical thinking skills of class XI. 1 Students of Madrasah Aliyah Madani Alauddin Pao-pao as an Experimental Class

Statistics	Critical Thinking Skills	
	Pre-Test	Post-Test
Number of Samples	24	24
Lowest Value	55	80
Highest Value	75	97
Mean	62.38	87. 92
Standard Deviation	6.34	5.46

The results of the descriptive statistical data test obtained are entered into the established categorization, then the frequency and percentage will be obtained for the critical thinking skills of class XI.1 students as an experimental class in the biology subject of the motor system material at Madrasah Aliyah Madani Alauddin Pao-pao. The categorization consists of low, medium and high categories. The categorization can be seen in the frequency distribution table and percentage of test results before and after the application of the SM2CL learning model to students' critical thinking skills below:

Table 5. Frequency Distribution and Percentage of Pre-Test Results of Critical Thinking Skills of Class XI.1 Students of Madrasah Aliyah Madani Alauddin Pao Pao as an Experimental Class

Statistics	Category	Critical Thinking Skills	
		Frequency	Percentage
$X < 56.04$	Low	7	29%
$56.04 \leq X < 68.71$	Medium	13	54%
$68.71 \leq X$	High	4	17%
	Number	24	100%

Based on the frequency and percentage distribution table above before the SM2CL learning model was implemented, it can be seen that there are students whose critical thinking ability test results are in the "low" category with a frequency of 7 and a percentage of 29%. In the "medium" category there is a frequency of 13 with a percentage of 54% and in the "high" category there is a frequency of 4 with a percentage of 17% in class XI.1 as the experimental class.

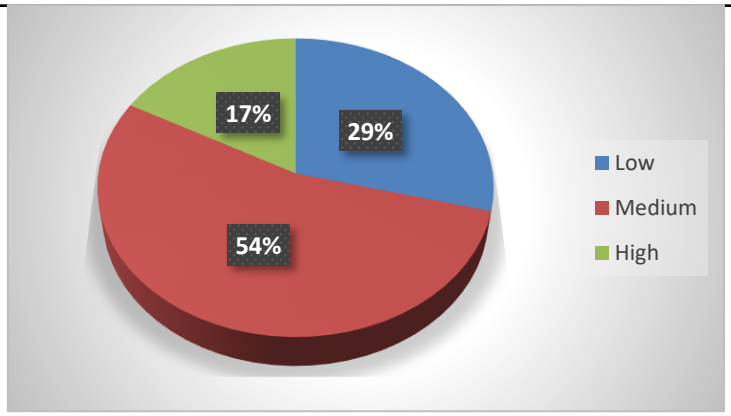

Figure 1. Results of the Pre-Test of Critical Thinking Skills of Class XI.1 Students of Madrasah Aliyah Madani Alauddin Pao-pao as an Experimental Class

Next is the description of the post-test results of critical thinking skills of class XI.1 students

Table 6. Frequency Distribution and Percentage of Post-Test Results of Critical Thinking Skills of Class XI.1 Students of Madrasah Aliyah Madani Alauddin Pao-pao as an Experimental Class

Statistics	Category	Critical Thinking Skills	
		Frequency	Percentage
$X < 82.46$	Low	4	16.7%
$82.46 \leq X < 93.38$	Medium	15	62.5%
$93.38 \leq X$	High	5	20.8%
	Number	24	100%

Based on the frequency and percentage distribution table above after the SM2CL learning model was implemented, it can be stated that there are students whose critical thinking ability test results are in the "low" category with a frequency of 4 and a percentage of 16.7%. In the "medium" category there is a frequency of 15 with a percentage of 62.5% and in the "high" category there is a frequency of 5 with a percentage of 20.8% in class XI as an experimental class that has implemented the SM2CL learning model. The following is presented in the form of a pie chart to clarify the description of the test results after the implementation of the SM2CL learning model on the critical thinking abilities of class XI.1 students as an experimental class.

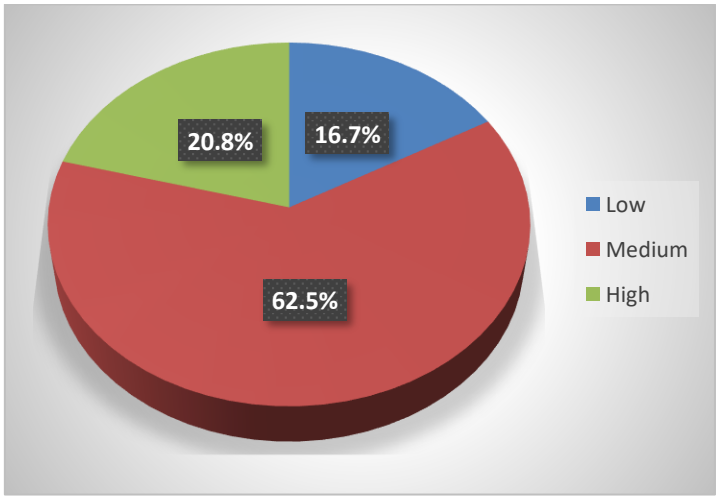

Figure 2. Post-Test Results of Critical Thinking Skills of Class XI.1 Students of Madrasah Aliyah Madani Alauddin Pao-pao

The following are descriptive statistics of the results of the critical thinking ability test of students as a control class, where the data was processed using SPSS version 24 as in the table below.:

Table 7. Descriptive Statistics of the Results of the Pretest and Posttest of Critical Thinking Skills of Class XI.1 Students of Madrasah Aliyah Madani Alauddin Pao-pao as the Control Class

Statistics	Critical Thinking Skills	
	Pre-Test	Post-Test
Number of Samples	23	23
Lowest Value	50	62
Highest Value	70	80
Mean	60.43	69. 61
Standard Deviation	6.73	5.28

The results of the descriptive statistical data test obtained are entered into the established categorization, then the frequency and percentage will be obtained for the critical thinking ability of class XI.2 students as a control class in the biology subject of the motor system material at Madrasah Aliyah Madani Alauddin Pao-pao. The categorization consists of low, medium and high categories. The categorization can be seen in the frequency distribution table and percentage of the results of the students' critical thinking ability test below:

Table 8. Frequency Distribution and Percentage of Pre-Test Results of Critical Thinking Skills of Class XI.2 Students of Madrasah Aliyah Madani Alauddin Pao Pao as a Control Class

Statistics	Category	Critical Thinking Skills	
		Frequency	Percentage
X < 53.71	Low	6	26%
53.71 ≤ X < 67.16	Medium	13	54%
67.16 ≤ X	High	4	17%
	Number	23	100%

Based on the frequency and percentage distribution table above in class XI.2 as a control class that was not given the SM2CL model treatment, where this learning model is one of the models that invites students to think. From the table above, it can be seen that there are students whose critical thinking ability test results are in the "low" category with a frequency of 6 and a percentage of 26%. In the "medium" category, a frequency of 13 was obtained with a percentage of 57% and in the "high" category, a frequency of 4 was obtained with a percentage of 17%. The following is presented in the form of a pie chart to clarify the description of the results of the critical thinking ability test of class XI.2 students as a control class that was not given the SM2CL learning model treatment.

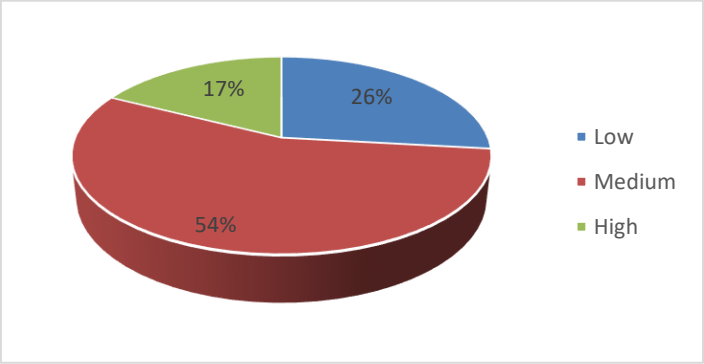

Figure 3. Results of the Pre-Test of Critical Thinking Skills of Class XI.2 Students of Madrasah Aliyah Madani Alauddin Pao-pao as the Control Class

Next, the results for the description of the post-test results of the critical thinking skills of class XI.2 students are presented in table 9 below:

Table 9. Frequency Distribution and Percentage of Post-Test Results of Critical Thinking Skills of Class XI.2 Madrasah Aliyah Madani Alauddin Pao-pao Students as the Control Class

Statistics	Category	Critical Thinking Skills	
		Frequency	Percentage
X < 64.33	Low	3	13%
64.33 ≤ X < 74.89	Medium	16	70%
74.89 ≤ X	High	4	17%
	Total	23	100%

Based on the frequency and percentage distribution table above in class XI.2 as a control class that was not given the SM2CL model treatment, where this learning model is one of the models that invites students to think. From the table above, it can be seen that there are students whose critical thinking ability test results are in the "low" category with a frequency of 3 and a percentage of 13%. In the "medium" category, a frequency of 16 was obtained with a percentage of 70% and in the "high" category, a frequency of 4 was obtained with a percentage of 17%. The following is presented in the form of a pie chart to clarify the description of the results of the critical thinking ability test of class XI.2 students as a control class that was not given the SM2CL learning model treatment.

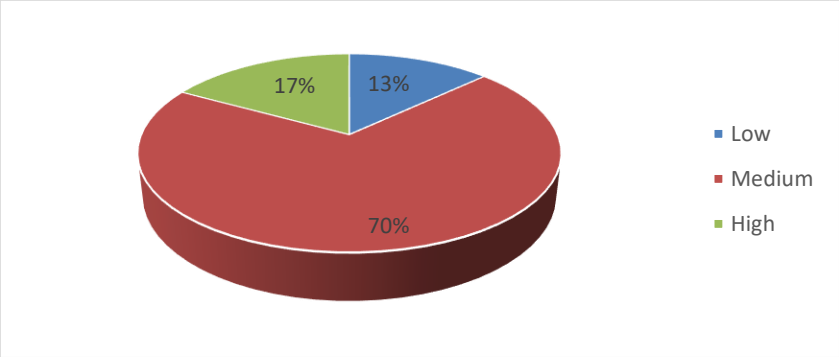

Figure 4. Post-Test Results of Critical Thinking Skills of Class XI.2 Students of Madrasah Aliyah Madani Alauddin Pao-pao as a Control Class

Based on the results of the research that has been conducted on students of class XI.1 as a class that was given treatment at Madrasah Aliyah Madani Alauddin Pao-pao with a total of 24 students, data can be collected through a questionnaire that was completed by the students themselves as respondents. The following are descriptive statistics of students' critical thinking attitudes as an experimental class where the data was processed using SPSS version 24 as in the table below:

Table 10. Descriptive Statistics of Critical Thinking Attitude Scale of Students of Class XI.1 and XI.2 Madrasah Aliyah Madani Alauddin Pao-pao as Experimental Class

Statistics	Critical Thinking Attitude	
	XI.1	XI.2
Number of Samples	23	23
Lowest Value	76	59
Highest Value	98	79
Mean	84.5	69. 74
Standard Deviation	6.96	4.86

The results of the descriptive statistical data test obtained are entered into the established categorization, then the frequency and percentage will be obtained for the scale of critical thinking attitudes of class XI.1 students as an experimental class after the application of the SM2CL learning model to strengthen the results of the critical thinking ability test of students in the subject of biology, material on the motor system at Madrasah Aliyah Madani Alauddin Pao-pao. The categorization consists of low, medium and high categories. The categorization can be seen in the frequency distribution table and percentage of students' critical thinking attitudes below:

Table 8. Frequency Distribution and Percentage of Critical Thinking Attitude Scale of Class XI.1 Students of Madrasah Aliyah Madani Alauddin Pao-pao as an Experimental Class

Statistics	Category	Critical Thinking Skills	
		Frequency	Percentage
$X < 64.33$	Low	1	4%
$64.33 \leq X < 74.89$	Medium	17	71%
$74.89 \leq X$	High	6	25%
	Total	24	100%

Based on the frequency and percentage distribution table above after the implementation of the SM2CL learning model, it can be seen that there are students whose critical thinking attitude questionnaire results are in the "low" category with a frequency of 1 and a percentage of 4% in class XI.1 as an experimental class that has

been given a learning model treatment that invites students to think, namely the SM2CL model. In the "medium" category there is a frequency of 17 with a percentage of 71%. While in the "high" category, a frequency of 6 with a percentage of 25% is obtained. The following is presented in the form of a pie chart to clarify the description of the critical thinking attitude scale of class XI.1 students as an experimental class that was given the SM2CL learning model treatment. The following is presented in the form of a pie chart to clarify the description of the critical thinking attitude scale of class XI.1 students as an experimental class that was given the SM2CL learning model treatment.

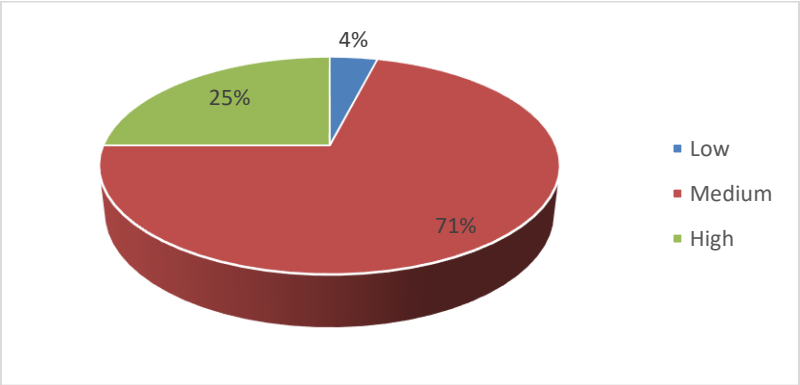

Figure 5. Results of the Critical Thinking Attitude Scale of Class XI.1 Madrasah Aliyah Madani Alauddin Pao-pao Students as an Experimental Class

Next, this section will answer the third problem formulation, namely whether there is an influence of the synectics, mind maps, cooperative learning (SM2CL) learning model on the critical thinking skills of class XI.1 Madrasah Aliyah Madani Alauddin Pao-pao students in biology. The data obtained in this section were analyzed using inferential statistical analysis. To find out whether there is a significant increase in the critical thinking skills of students in the experimental class XI.1 and the control class XI.2 Madrasah Aliyah Madani Alauddin Pao-pao, a hypothesis test was carried out. Hypothesis testing is used to answer the hypothesis that has been formulated using a t-test with Paired - Samples T test analysis. Before testing the hypothesis, a prerequisite test consisting of a normality test and a homogeneity test is carried out to determine whether the data is normal and homogeneous.

The following is the output of SPSS version 24 for testing the hypothesis of the pre-test and post-test results of students' critical thinking skills in the experimental class and control class. Normality testing is carried out on the critical thinking ability test results of students in classes XI.1 and XI.2. The significant level in the Kolmogorov Smirnov test is that if the sig value $<\alpha = 0.05$ means the data is not normal and if the sig value $>\alpha = 0.05$ means the data is normal. The following are the results of the Kolmogorov Smirnov normality test obtained which can be seen in the table below:

Table 11. Normality Test of Pre-Test and Post-Test One-Sample Kolmogorov Smirnov Test in Class XI.1 and XI.2 Madrasah Aliyah Madani Alauddin Pao-pao

	Asymp. Sig. (2-tailed)	
	XI.1	XI.2
N	24	23
Critical Thinking Skills Pre-Test	0.073	0.146
Critical Thinking Skills Post-Test	0.173	0.186

Based on the output of the normality test of the data processing results above using the Kolmogorov Smirnov test, the pre-test value of students' critical thinking ability was 0.073 and the post-test value of students' critical thinking ability was 0.173. Thus, it can be concluded that the data from the critical thinking ability test results of students in biology as an experimental class before and after being given both treatments are normally distributed, because the sig value is greater than α or (0.073> 0.05) and (0.173> 0.05) which means H_0 is accepted. Based on the output of the normality test of the data processing results above using the Kolmogorov Smirnov test, the pre-test value of students' critical thinking ability was 0.146 and the post-test value of students' critical thinking ability was 0.186. Thus, it can be concluded that the data on the results of the critical thinking ability test of students in biology as a control class (without treatment) are also normally distributed because the sig value is greater than α or (0.146> 0.05) and (0.186> 0.05) which means that H_0 is accepted.

The following is the output of SPSS version 24 for the homogeneity test of the results of critical thinking ability data and the scale of students' critical thinking ability:

Table 12. Test of homogeneity of variances pre-test and post-test in class XI.1 and XI.2 Madrasah Aliyah Madani Alauddin Pao-pao

	Levene Statistic	df1	df2	Sig.
Critical Thinking Skills Pre-Test	0.294	1	45	0.591
Critical Thinking Skills Post-Test	0.188	1	45	0.667

From the results of data analysis processing in the table above, the homogeneity test of class XI.1 and XI.2 was obtained where the pre-test value of students' critical thinking ability was 0.591 and the post-test value of students' critical thinking ability was 0.667. Thus, it can be concluded that the data on students' critical thinking ability in biology subjects is homogeneous because the sig value is greater than α or (0.591> 0.05) and (0.667> 0.05) which means H_0 is accepted. Paired-Samples T-test analysis was used to see the effect before and after the implementation of the synectics, mind maps, cooperative learning (SM2CL) learning model on the thinking ability of class XI.1 students in biology subjects at Madrasah Aliyah Madani Alauddin Pao-pao, in other words to test the proposed hypothesis. Based on the results obtained using SPSS version 24, the following analysis results were obtained:

Table 12. Results of the paired samples test of critical thinking skills of class XI.1 students

Paired Differences	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	Sig. (2 tailed)
				Lower	Upper			
Pre-Tes KBK - Post Tes KBK	25.542	2.637	.538	24.428	26.655	47.448	23	0.000

In the Paired Samples Test results table, a mean difference of 25.542 was obtained, which means the difference in the value of students' critical thinking ability test results between before and after the SM2CL learning model was applied with the movement system material. A positive value means that after being given the SM2CL learning model, the value of students' critical thinking ability test results is higher than before being given the SM2CL learning model with the movement system material. Furthermore, this table also obtained a std. error mean of 0.538 which shows the standard error number of the average difference. Furthermore, the most important result of this table is the statistical value of t = 47.448 with db = 23 and the sig. or p-value = 0.000 <0.05 or H0 is rejected. Thus, there is a difference in the value of students' critical thinking ability test results before and after being given the SM2CL learning model treatment. So it can be concluded that "there is an influence of the SM2CL learning model on the critical thinking ability of class XI.1 in biology subjects". The results of the hypothesis test of students' critical thinking ability can be seen in the paired samples test table below:

Table 13. Results of the paired samples test of critical thinking skills of class XI.2 students

Paired Differences	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	Sig. (2 tailed)
				Lower	Upper			
Pre-Tes KBK - Post Tes KBK	9.174	2.516	.525	10.262	8.086	17.484	22	0.000

In the Paired Samples Test results table, a mean difference of 9.174 was obtained, which means that the difference in the value of students' critical thinking ability test results between the initial and final tests was different when the movement system material was given but the SM2CL learning model was not applied. A positive value means that the initial test that was not given the SM2CL learning model with the movement system metric, the value of students' critical thinking ability test results was not much different from the final test that was not given the application of the SM2CL learning model. Furthermore, this table also obtained a std. error mean of 0.525 which shows the standard error number of the average difference. Furthermore, the most important result of this table is the statistical value of t = 17.484 with db = 22 and the sig. or p-value = 0.000 <0.05 or H0 is rejected. Thus, there is a difference in the value of the initial and final critical thinking ability test results of students who were not given the SM2CL learning model treatment. The difference in the results of the initial and final tests of students in the control class was caused by the test questions containing questions that had not been previously studied by students.

The effectiveness of the SM2CL learning model in enhancing students' critical thinking skills can be explained from a theoretical perspective that highlights the interaction of its components—synectics, mind mapping, and cooperative learning—which collectively support metacognitive development. Synectics encourages analogical thinking, allowing students to connect abstract biological concepts with real-life experiences. Mind

mapping functions as a visual tool that helps organize and connect knowledge hierarchically, thereby enhancing information processing and retrieval. When combined with cooperative learning, students not only build individual understanding but also engage in social negotiation and reflection, which are key processes in metacognitive regulation. This synergy encourages students to plan, monitor, and evaluate their thinking strategies during collaborative tasks, thus improving their awareness and control over their own learning processes. A study by Ismail et al. [46] found that the combination of mind mapping and cooperative learning significantly improved programming performance, problem-solving skills, and metacognitive knowledge among computer science students.

From a metacognitive perspective, students engaged in SM2CL-based activities tend to experience an improvement in higher-order thinking, as this model facilitates active knowledge construction. Cooperative learning promotes accountability and peer teaching, which require students to reflect on their own understanding. The use of mind maps helps them visualize the relationships between concepts, fostering deeper comprehension. The reflective elements embedded in synectics, combined with group discussions in cooperative learning, create a classroom culture in which students are encouraged to evaluate and adjust their thinking—core practices in metacognitive development. A study by Herlanti et al. [47] found that learning strategies combining mind mapping and reciprocal teaching significantly enhanced students' metacognitive knowledge in biology education.

This study presents a novelty by integrating the SM2CL (Synectics, Mind Mapping, Cooperative Learning) model into biology instruction to enhance students' critical thinking skills—an approach that has rarely been explored in a unified and empirical manner. The findings revealed that students in the experimental group showed significantly higher gains in both critical thinking skills and attitudes compared to those in the control group. This indicates that the SM2CL model is effective in fostering both cognitive and metacognitive growth. The implication of these results underscores the importance of incorporating innovative, multi-faceted learning strategies—such as visual concept mapping, collaborative problem-solving, and creative analogical thinking—into senior high school science curricula to support the development of 21st-century skills.

The main contribution of this study lies in providing empirical evidence for the effectiveness of a multistrategy instructional model in promoting higher-order thinking in science education. By demonstrating the synergy among synectics, mind mapping, and cooperative learning, this research offers valuable insights for educators seeking to improve student engagement and critical thinking outcomes. However, the study is limited by its small sample size and focus on a single school, which may affect the generalizability of the findings. Future research involving more diverse populations and broader contexts is recommended to validate and expand upon these results.

4. CONCLUSION

The SM2CL learning model (Synectics, Mind Mapping, Cooperative Learning) effectively enhances students' critical thinking skills and attitudes in biology among eleventh-grade students. Its implementation led to a significantly greater improvement in both pre-test and post-test scores in the experimental class compared to the control class, with statistically significant results. By integrating creative, visual, and collaborative strategies, the model facilitates higher-order thinking processes and supports students' metacognitive development. SM2CL presents a promising instructional alternative to foster 21st-century skills in secondary education settings. This implies that integrating multi-strategy learning models like SM2CL into science instruction can be a powerful approach to cultivating critical thinking and metacognitive skills in high school students. Future research is recommended to apply the SM2CL model across diverse subjects, student populations, and educational settings to further validate its effectiveness and broaden its applicability.

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