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ORIGINAL RESEARCH

The Means-Ends Analysis (MEA) Model Assisted by Question Cards on Students' Critical Thinking Skills in the Material of Work and Energy

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Abstrack

This This study is a pre-experimental study that aims to describe students' communication skills before and after the implementation of virtual laboratories with problem-based learning, as well as analyze the improvement of students' communication skills in high school after participating in learning using virtual laboratories with problem-based learning. The design in this study is a One Group Pretest-Posttest design, with a population and sample of 30 students selected using saturated sampling techniques. The instrument used to collect data is an essay test consisting of 15 questions developed according to the indicators of students' communication skills, namely interpreting graphs, interpreting tables, interpreting images, changing the form of presentation, drawing conclusions, providing reasons, and explaining the results of observations. The data obtained in this study are quantitative data analyzed using descriptive statistics and inferential statistics. Based on the research data, it was found that high school students' communication skills are in the moderate category with an average N-Gain value of 0.68. Meanwhile, the results of the significance test using the Wilcoxon Signed Rank test showed a p-value of 0.001, which is smaller than 0.05. This indicates that the implementation of virtual laboratories with problem-based learning can improve students' communication skills.

Keywords: Virtual Laboratory · Problem Based Learning · Communication Skills

INTRODUCTION

Education is a process of transferring knowledge from educators to students with the aim of providing an understanding of the material adapted to the applicable curriculum. The "Kurikulum Merdeka" is the curriculum currently implemented in Indonesia. According to the Kurikulum Merdeka, it aims to equip students to face life in the modern era. The process of improving students' critical thinking skills must always be practiced continuously, because these skills play a crucial role in facing the challenges of the globalization era . In the era of globalization, there is an abundance of technology and information that results in the expansion of knowledge that impacts life, so students must think critically to accept or reject the information obtained.

Creative thinking, creativity and innovation, collaboration, communication, critical thinking, and problem solving are provisions for students as part of 21st-century competencies . Critical thinking skills emphasize the thought process of students to identify and analyze something by paying attention to various things to choose a reasonable solution . In the field of

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science, critical thinking skills are needed for the process of observing and choosing the right solution to solve problems . Critical thinking is a learning tool that plays a role in realizing learning in improving and honing thinking by engaging responsively in learning activities . Students in learning activities must be responsive so they can easily understand concepts and train their thinking skills, one of which is in learning physics.

Physics is a subject to improve knowledge and skills with high quality and competence in which there are various phenomena related to life as well as concepts and knowledge from the findings of experts. In learning physics, the emphasis is on the learning experience of students who are directly involved in the process of constructing the material . In learning physics is not only related to theory and formulas, but there is an understanding of various concepts that must be learned in the learning process . Students with low critical thinking skills tend to be passive in learning activities because they do not have an understanding of the concepts they have and only receive knowledge from the teacher .

Based on the results of interviews at SMA Negeri 1 Cineam, it was found that physics learning tends to be dominated by the role of the teacher, with students' roles only observing and writing the material. In learning, conventional learning models tend to be used frequently, and in the process, students do not have the opportunity to be active in learning activities. Thus, students' critical thinking skills are classified as very low. Then, the information obtained from the interviews was reinforced by a test of students' critical thinking skills, with a percentage of 10.1% falling into the very low category.

Low critical thinking skills need to be addressed by using innovative learning models that actively involve students in learning activities, namely through the application of the Means-Ends Analysis (MEA) model. The MEA model can provide space for students to determine goals in solving a problem they face and determine ways to help solve the problem.

The MEA model is a model with sequential stages, so it can develop students' abilities to solve problems by analyzing in depth in identifying and determining the right solution based on the results of students' thinking . The MEA model plays an important role in the problem-solving process with a heuristic approach obtained from several stages to help students achieve the expected goals . Based on this definition, it is known that the MEA model is a model with a learning center on students, because students play a role in every stage of learning carried out, starting from identifying problems to developing ways to solve problems. The syntax of the MEA model according to is providing material with a heuristic-based problem approach, elaborating sub-problems into simple ones, analyzing problems, compiling sub-problems so that there is connectivity, and choosing a solution strategy.

In this modern era, humans must possess critical thinking skills as a means of filtering information, whether accepting or rejecting information through data, facts, and reasonable evidence . According to Ennis, indicators of critical thinking skills are grouped into five indicators: providing simple explanations, building basic skills, drawing conclusions, providing further explanations, and developing strategies and tactics.

From the results of previous research, information was obtained that the Means-Ends Analysis (MEA) model had an effect on students' critical mathematical thinking skills with values $t_{hitung} = 2{,}61$ and $t_{tabel} = 1{,}67$. In addition, the Means-Ends Analysis (MEA) model also has an influence on improving students' grammar learning outcomes with $t_{hitung} =$

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15,46 and $t_{tabel} = 2,09$. From the results of previous research, the use of the Means-Ends Analysis (MEA) model for critical thinking skills has not used assistance to hone critical thinking skills and increase student interest in the learning process, therefore in this study the use of the Means-Ends Analysis (MEA) model assisted by question cards will be carried out so that students are trained to get used to solving problems with a sense of responsibility, cooperation, and active responses in learning.

Question cards are cards containing questions as an alternative medium to foster independent learning and increase students' active responses in learning. Question cards are a means of presenting questions to practice critical thinking skills. They are designed in an engaging way using the Canva application, so that students have an attraction when learning and train students' independence in thinking to answer questions.

Based on the background that has been explained, this study aims to determine the effect of the Means-Ends Analysis (MEA) model with the help of question cards on work and energy material, as a means to train students' habits in solving problems so that students' critical thinking skills are more honed through the application of the Means-Ends Analysis (MEA) model with a systematically arranged syntax for problem solving.

METHOD

The research was conducted at a high school in Tasikmalaya Regency. The quasi-experimental method was used in the research. The research population was 8 classes of 10th grade students at a high school in Tasikmalaya Regency, with a total of 267 students. The research sample was selected using a purposive sampling technique. Purposive sampling technique is a sampling technique that is taken based on certain considerations. The sample was selected based on considerations of the average value and standard deviation that were close so that the selected classes were class X-1 with a total of 33 students consisting of 15 males and 18 females, then class X-2 with a total of 33 students consisting of 12 males and 21 females.

In collecting data, using descriptive test questions as many as 9 items, in each item measures each indicator of critical thinking skills, namely providing simple explanations, building basic skills, drawing conclusions, providing further explanations, and arranging strategies and tactics. The maximum score for each item is 25 so that for 9 items the maximum score is 225. Before the questions were used, a validity test was carried out by 2 experts, namely physics education lecturers. In giving validity scores using the formula according to. The scoring is calculated using equation (1).

$$V = \frac{\sum s}{\left[n\left(c-1\right)\right]} \tag{1}$$

where: $s = r - l_0$; l_0 = low rating number; c = high rating score; r = number of validators; and n = number of validators. The V coefficient value is then interpreted according to Table 1.

Table 1. Interpretation Coefficient Validity

Coefficient Value	Interpretation
$0,6 \leq V \leq 1$	Valid
$V < 0,6$	Invalid

Source : (Azwar, 2012)

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The trial was conducted on January 21, 2025, in class XI MIPA 2 at a high school in Tasikmalaya district with 28 students. The instrument trial included validity and reliability tests. The validity test was conducted using *product moment* correlation using raw scores, as in equation (2).

$$r_{xy} = \frac{N\sum XY - \left(\sum X\right)\left(\sum Y\right)}{\sqrt{\left[N\sum X^2 - \left(\sum X\right)^2\right]\left[N\sum Y^2 - \left(\sum Y\right)^2\right]}} \tag{2}$$

where r_{xy} = correlation coefficient between variables X and Y; X = score for each question; Y = total score; and N = total number of students. If $r_{hitung} > r_{tabel}$ the question item is declared valid, then if $r_{hitung} < r_{tabel}$ the question item is declared invalid. The reliability test functions to determine the consistency of the instrument that will be used, then calculations are carried out using the Cronbach alpha reliability test formula according to equation (3).

$$r_{11} = \frac{k}{k-1}\left(1 - \frac{\sum \sigma_i^2}{\sigma_t^2}\right) \tag{3}$$

where r_{11}= reliability coefficient; $\sum \sigma_i^2$= total variance of scores for each component; σ_i^2= total score variance; k = number of question; and N = number of respondents. The interpretation of the reliability test according to Guilford is as seen Table 2.

Table 1 Interpretation of Reliability Test

Range	Interpretation
$0{,}00 < r_{11} < 0{,}20$	Very Low
$0{,}20 < r_{11} < 0{,}40$	Low
$0{,}40 < r_{11} < 0{,}60$	Medium
$0{,}60 < r_{11} < 0{,}80$	High
$0{,}80 < r_{11} < 1{,}00$	Very high

The matching-only posttest-only control group design was used in the study. Researchers matched subjects in the experimental and control classes after being treated with different learning models as seen in Table 3.

Table 2 Research Design

Group Experiment	M	X	O
Group Control	M	C	O

where M = subject; X = given treatment of the application of the MEA model assisted by Question Cards; C = given treatment by applying the direct instruction model assisted by Question Cards; and O = posttest.

The experimental class and control class were determined through the highest and lowest daily physics test scores, the experimental class was class X-1 with an average daily physics test score of 60 while the control class was class X-2 with an average daily physics test score of 65.3. To see the influence of the model to be studied, the Means-Ends Analysis (MEA) model was applied in class X-1, to see whether the influence of the model made the scores of students in class X-1 greater or not compared to class X-2.

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Posttest scores were obtained using scoring guidelines developed by and adapted through as shown in Table 4.

Table 3 Scoring Rubric Skills Critical thinking

Score	Response Students' Response to Questions
5	All draft correct , clear and specific All description answer correct , clear , and specific , supported by strong reasons , correct , arguments clear thought process okay , all draft each other related and integrated Good and correct grammar All aspects are visible, the evidence is good and balanced
4	Most of the draft true , clear However not enough specific Most of the description answer true , clear , but not enough specific thought process well , partly big draft each other related and integrated Grammar good and right , there is error small All aspect visible , but Not yet balanced
3	Fraction draft correct and clear Fraction description answer correct and clear However reasons and arguments No clear thought process Enough well , partly small each other related Grammar Enough okay , there is spelling error Most of the visible aspects Correct
2	Draft not enough focus or excessive or doubtful Description answer No support thought process not enough good concept No each other related Grammar good , sentence No complete Fraction visible aspects Correct
1	All draft No Correct or No sufficient Reason not Correct thought process No Good Grammar No Good In a way overall aspect No sufficient
0	n't any answer or wrong answer

Then the posttest score is calculated by finding the percentage of the score, the method for calculating the posttest score of students is as follows.

$$P = \frac{x}{x_i} \times 100\% \tag{4}$$

with P = percentage value; x = value obtained; and x_i = maximum value on one indikator. Then the student's scores are interpreted according to the categorization table in Table 5.

Table 4. Categorization Skills Critical thinking

Percentage (%)	Category
$81{,}25 < x \leq 100$	Very high
$71{,}50 < x \leq 81{,}25$	High
$62{,}50 < x \leq 71{,}50$	Medium
$43{,}75 < x \leq 62{,}50$	Low
$0 < x \leq 43{,}75$	Very Low

RESULT AND DISCUSSION

Results

The research was conducted in classes X-1 and X-2, with two learning sessions. A posttest was then administered, with the results presented in Table 6.

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Table 5 Statistical Data

Statistical Data	Class	
	Experiment	Control
N	32	32
Maximum Score	225	225
Lowest Score	177	117
Highest Score	223	174
Average	201.75	143.38
Variance	204.84	286.69
Standard Deviation	14.31	16.93

The results of the critical thinking skills measurement in Table 5 show a significant difference in average scores between the experimental and control classes. Therefore, it can be concluded that the experimental class scored higher than the control class. The overall percentage of students' *posttest* scores for each indicator is presented in Table 7.

Table 6 Average Percentage Score for Each Critical Thinking Skills Indicator

No	Indicator	Class Experiment		Class Control	
		Percentage (%)	Category	Percentage (%)	Category
1.	Elementary clarification	95.49	Very high	74.93	High
2.	Basic support	94.79	Very high	59.30	Low
3.	Inference	90.69	Very high	71.53	High
4.	Advance clarification	87.5	Very high	61.18	Low
5.	Strategy and tactics	80.62	High	52.57	Low
Average		89.82	Very high	63.90	Medium

From Table 7, it is known that the critical thinking skills score in the experimental class is superior to the control class because in each indicator the percentage value is greater than the control class, which indicates that the model applied in the experimental class has an effect on the percentage of student achievement in each indicator.

Then carry out the pre-requisite test calculations, namely the normality test, which is known that χ^2_{tabel} is 12.83 and χ^2_{hitung} experimental class was 10.11 and χ^2_{hitung} control class was 9.11 so $\chi^2_{hitung} < \chi^2_{tabel}$ which means that all groups have a normal distribution.

After that, a homogeneity test using Fisher's test was conducted. The results of the homogeneity test using Fisher's test with a $_{\text{calculated F value}} < F_{\text{ table,}}$ namely 1.39 <1.80, then $H0_{\text{ is}}$ accepted and $Ha_{\text{ is}}$ rejected, which means that the scores of the experimental class and the control class have the same variance.

From the results of the normality test and homogeneity test, it was found that both classes had a normal distribution and had the same variance, so that the hypothesis test used the t-test with the results obtained $t_{\text{ count}} > t_{\text{ table}}$ with a value of 14.89 > 1.67, which means that the MEA model assisted by question cards has a positive impact on students' critical thinking skills.

The use of the MEA model through question cards significantly impacts critical thinking skills because students have a direct, active role in learning. This aligns with the opinion of Telaumbanua & Harefa (2022) that the MEA model can guide students in developing ways of thinking to solve problems.

Furthermore, question cards are used as a medium to train students to sharpen their minds to solve problems. Question cards also play a role in fostering active learning through problem-

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solving based on given directions. This aligns with previous research that shows that active student participation in learning using question cards can stimulate reflective thinking.

The posttest results using the Means-Ends Analysis (MEA) model with the help of question cards were superior to the posttest results in the control class using the direct instruction model with the help of question cards. This difference in scores was due to student participation in the learning activities. In the experimental class, students played an active role, while in the control class, they played a passive role. This is in accordance with the opinion that in the direct instruction model, learning activities are fully centered on the teacher, while students tend to be passive, only listening and following the teacher's directions.

Furthermore, during the question card process, students in the control class were directly guided by the teacher in solving the questions until they were able to answer them, thus not having much opportunity to construct their own understanding. Meanwhile, in the experimental class, the teacher's role was limited to providing instructions with the goal of encouraging students to practice their thinking skills. Therefore, even though both classes were given question card assistance, the training in critical thinking skills was certainly different, due to the different roles of the students in it.

The first syntax is explaining the material with a heuristic-based problem-solving approach. The teacher explains the material and then provides a question card after each sub-topic is explained, so that students are able to immediately reflect on the knowledge gained by answering questions and then relating them to relevant concepts. The indicator of providing a simple explanation is trained using the syntax of explaining the material with a heuristic-based problem-solving approach. In the indicator of providing a simple explanation, the percentage of students' scores in the experimental class is greater than the control class. In this indicator, students explain the material simply according to their understanding of a particular concept. In the indicator of providing a simple explanation, students are given 2 question cards in both the experimental and control classes. Students in both classes follow the instructions well, but there are differences in their answers, as shown in Figure 1.

In Figure 1, it can be seen that the answers of students in the experimental class were able to provide answers according to their own thoughts and then linked them to relevant concepts, whereas in the control class, students were only able to provide answers without linking them to relevant concepts. The second syntax is to simplify the sub-problems. The teacher provides worksheets and question cards, then instructs students to gather information through simple experiments carried out in groups. At this stage, students each have their own role. This syntax plays a role in practicing indicators for building basic skills, so that the results of these indicators in the experimental class are superior to the control class. This is because in the control class, students only watch the teacher conduct experiments and then write down the findings from the experiments that have been carried out by the teacher.

The third syntax is identifying the problem. Students at this stage write down the experimental results obtained and then put them in a table of experimental results. After that, they continue by identifying the focus of the problem that must be resolved. The indicator provides further explanations trained in the third syntax, so that the indicator score in the experimental class is 87.5% superior to the control class which reached 61.18%. In the control class, students are assisted by the teacher in the process of gathering information to determine the focus of the problem for which a solution must be sought.

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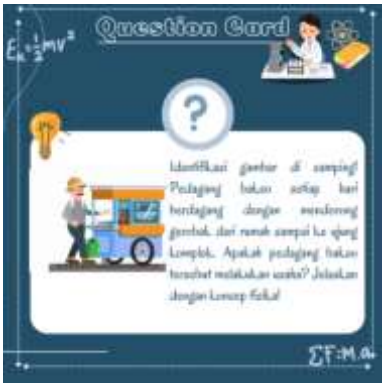
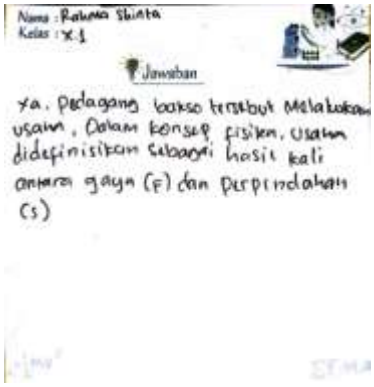
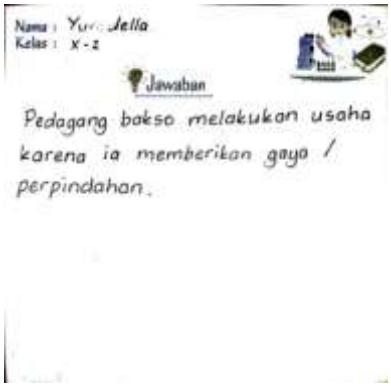


(a)



(b)



(c)

Figure 1a) Question in Question Card, (b) Answer Experimental Class Students , (c) Answers Control Class Students

The fourth syntax involves constructing sub-problems to create connectivity. At this stage, the teacher instructs students to answer questions as a basis for consideration in developing concepts from the general to the specific. The fourth syntax trains the indicator for drawing conclusions, resulting in a score of 90.69% in the experimental class, compared to 71.53% in the control class.

In the fifth syntax, namely choosing a solution strategy, the teacher instructed students to start discussing in determining the right solution to solve the problem by referring to considerations from data information sources through the previous syntax. Indicators for managing strategies and tactics were practiced in the fifth syntax, so that this indicator in the experimental class was 80.62% superior to the control class which only reached 52.57%.

The results show that the percentage scores for the five indicators indicate that, although both classes received question cards , their critical thinking skills training differed. This is undoubtedly influenced by the learning model used. The experimental class involved active student participation, while the control class tended to be dominated by the teacher.

The indicators in the fifth syntax have lower percentages than the others, as this syntax requires a significant amount of discussion time. In the study, researchers encountered difficulties in effectively utilizing the available discussion time, resulting in suboptimal discussion time.

Thus, learning activities in the experimental class using the Means-Ends Analysis (MEA) model contributed better to training students' critical thinking skills through the stages of identification, analysis, strategy selection, and implementation of appropriate solutions to solve problems. This was able to have a positive impact on improving indicator achievement

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compared to the control class, because the syntax of the Means-Ends Analysis (MEA) model has a systematic and structured syntax for the problem-solving process through analysis and identification.

Based on the discussion that has been presented, research using the Means-Ends Analysis (MEA) model assisted by question cards is appropriate for use in physics learning on work and energy material in class X. These results are proven by the average posttest score in the class using the Means-Ends Analysis (MEA) model assisted by question cards is higher than the average posttest score in the class using the direct instruction model assisted by question cards. The Means-Ends Analysis (MEA) model has an effect on students' problem-solving abilities . Then the Means-Ends Analysis (MEA) model has an effect on students' numerical abilities . From the results of previous studies, it is known that the Means-Ends Analysis (MEA) model has an effect on students' problem-solving abilities and numerical abilities. Then this study was conducted to determine the effect of the MEA model assisted by question cards on students' critical thinking skills.

Through the process of data collection and analysis, the results obtained were that the Means-Ends Analysis (MEA) model assisted by question cards had an effect on students' critical thinking skills in the material of work and energy, with an average percentage value in the experimental class of 89.82% with a very high category, while in the control class it only reached 63.90% with a moderate category.

CONLUSION

Based on the research results, the percentage value of each indicator in the experimental class has very high and high indicators with an average percentage of 89.82%. Then the results of the hypothesis test show that $t_{hitung} > t_{tabel}$ with a value of $14{,}89 > 1{,}67$. So it can be concluded that the MEA model with the help of question cards has a positive impact on students' critical thinking skills in the material of work and energy.

AUTHOR CONTRIBUTION

Kania Dinata: Data curation, data analysis, and drafting articles. **Yanti Sofi Makiyah:** Monitoring, validation, writing articles, reviewing and editing. **Ernita Susanti**: Monitoring, validation, writing articles, reviewing and editing.

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