The Effect of Brainstorming-Assisted ARCS Model on Students' Critical Thinking Skills in Alternative Energy Concept

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Abstract - *Critical thinking skills are important in learning because they encompass conceptual understanding and rational decision-making. However, students' critical thinking skills are relatively low, and innovation in physics learning is minimal. Therefore, the ARCS model, supported by brainstorming, was implemented as an intervention. The study aims to identify the effect of the Attention, Relevance, Confidence, Satisfaction learning model assisted by brainstorming on students' critical thinking skills on alternative energy material in class X of SMA Negeri 1 Cihaurbeuti in the 2024/2025 academic year. The methodological design used is a quasi-experiment with a posttest only control group design structure. The study population includes 12 classes of class X, with purposive sampling of two classes, namely X-6 and X-8. The research measurement instrument is an instrument in the form of a descriptive assessment consisting of six questions arranged to represent all indicators of critical thinking skills. Hypothesis test analysis using the t-test produces a value of* $t_{count} = 13{,}13$ *which significantly exceeds the critical threshold of* $t_{table} = 1{,}68$ *at the significance level (*α *=0.05) thus stating that* H_0 *is rejected. Thus, the Attention, Relevance, Confidence, Satisfaction model assisted by brainstorming provides a significant contribution to students' critical thinking skills. This study recommends learning using the ARCS model combined with brainstorming methods to improve critical thinking skills and encourage student involvement in formulating ideas or solutions to problems collaboratively. Further research could empirically test the effectiveness of the combination of ARCS and brainstorming on different topics or with variations of other collaborative strategies.*

Keywords*: Alternative Energy; ARCS Learning Model; Brainstorming; Critical Thinking Skills.*

INTRODUCTION

Contemporary education in the 21st century requires students to internalize and operationalize essential competencies that fall into the 4C domain, namely: creativity and innovation as manifestations of the reconstructive capabilities of new ideas, critical thinking and problem-solving skills that reflect reflective analysis and solution-based synthesis of the complexity of problems, communication skills as the effective articulation of ideas across contexts, and collaboration as a cooperative capacity in the dynamics of interdependent work (Mu'minah H. I. & Aripin I., 2019). Developing these skills is important because the modern era is characterized by rapid growth of information and continues to change over time (Setiawan et al., 2018).

In the 21st century, critical thinking skills have become the main skills that must be developed because critical thinking is considered an important intellectual capital for students, as an essential element of thinking maturity so that it is very important to design a learning process that provides students with the opportunity to improve their critical thinking skills to the maximum (Aprina et al., 2024). Critical thinking skills are a logical and orderly thinking process in solving problems, including identifying issues, formulating solutions, evaluating information, and formulating ideas based on credible data (Saputri et al., 2020). The potential for critical thinking skills in students in the Independent Curriculum is still relatively low. This is influenced by low literacy and a lack of skills in understanding and solving problems logically and objectively (Pulungan et al., 2024). According to Kusuma et al (2024), it is explained that this skill is the main aspect that students need to master because it helps analyze assumptions, organize thoughts systematically, and solve problems faced through a rational approach. The indicators of reflective cognitive competence as formulated by Ennis in Suciono et al (2021) include: (1) Basic clarification or providing a simple explanation; (2) Building basic skills; (3) Inference; (4) Advance clarification; (5) Strategy and tactics.

A preliminary study was conducted at SMA Negeri 1 Cihaurbeuti using various methodological approaches, including participant observation, semi-structured interviews with physics teachers, and the use of diagnostic assessment instruments to measure students' critical thinking skills. Observations of the classroom learning process revealed that instructional interaction patterns were still centered on teacher dominance. This condition has an impact on the minimal active involvement of students in each phase of learning, which implicitly forms the characteristics of passive participation and low constructive contributions in learning activities which should be dialogical and reflective. In addition, during the learning process, students show a dominant tendency towards mechanistic cognitive activities, namely an emphasis on memorizing formulas and numerical manipulation, without adequate conceptual understanding of the underlying theoretical framework.

Based on interviews with teachers, it was found that students' critical thinking skills are still ineffective, so teachers need to provide more encouragement to encourage students to think more actively. Furthermore, ongoing learning practices are still teacher-centered, with conventional approaches being used more often than constructivist learning models that position students as active subjects in the knowledge-building process. This aspect corresponds to the perspective of Hairida (2016), which states that a pedagogical approach oriented towards the instructional role of educators is considered to have limited effectiveness in facilitating the actualization of students' critical thinking skills in the learning process being carried out.

The results of the examination using the implemented evaluative instrument indicate that the level of critical cognitive capabilities of students is categorically classified as inferior (low). The average percentage is 54.1%, indicating that the level of critical thinking skills of students at SMA Negeri 1 Cihaurbeuti has not yet reached an adequate category. Therefore, a strategy can be applied to improve students' critical thinking skills, namely by implementing a student-centered learning model, namely using the ARCS model supported by brainstorming techniques as reinforcement in the learning process.

The ARCS learning model is a learning approach that focuses on students improving and maintaining motivation in learning and developing critical thinking skills optimally (Farida & Indah, 2020). The ARCS learning model is based on four syntaxes, namely (1) attention; (2) relevance; (3) confidence; (4) satisfaction. This approach builds instructional conditions that motivate and encourage a disposition for continuous learning, thereby assisting students' cognitive internalization in optimally actualizing critical thinking skills (Maulidiya, 2024). The application of the ARCS learning model is synergized with the brainstorming approach because it encourages students to express all their ideas regarding the given problem, so that they are encouraged to think more deeply and develop creativity (Karim, 2017). In addition, the use of brainstorming strategies can provide many opportunities for students to be creative, generate many ideas through explanations, clarifications and participate in discussions to train and encourage critical thinking (Daniel, 2023).

The use of the brainstorming method can be interpolated in each syntax of the ARCS learning model as a strategic tool in initiating cognitive stimulus to deepen attention (Attention), actualize meaningful conceptual relationships (Relevance), affirm self-efficacy in the reasoning and argumentation process (Confidence), and construct learning experiences that have affective and satisfying value (Satisfaction). In this way, brainstorming not only increases creativity, but becomes effective in improving critical thinking skills in implementing ARCS model-based learning. Furthermore, previous research conducted by Nurhadi, M., & Susilo, (2020) stated that ARCS learning aims to awaken, stimulate, enhance, and maintain student motivation in learning. An adequate learning context can strengthen the development of students' critical thinking skills. The combination of the ARCS model and brainstorming is very effective because theoretically, the two approaches complement each other, and empirically, the combination of the two has been proven effective in improving students' critical thinking skills in science learning, including physics and alternative energy.

In line with the background, this study implemented the Attention, Relevance, Confidence, Satisfaction (ARCS) model assisted by brainstorming on alternative energy material for class X to determine its effect on students' critical thinking skills. This study is entitled "The Effect of the Attention, Relevance, Confidence, Satisfaction (ARCS) learning model assisted by brainstorming on students' critical thinking skills on alternative energy material in class X of SMA Negeri 1 Cihaurbeuti in the 2024/2025 academic year."

RESEARCH METHODS

This study employed a quasi-experimental research design as the primary approach to scientific investigation. Prior to the study, the researcher obtained official approval from the school, evidenced by a research implementation letter from SMA Negeri 1 Cihaurbeuti, as well as approval from the physics teacher and homeroom teacher. The study population included all 10th-grade students, comprising 12 classes with a total of 429 students. The design used was a posttest only control group, as shown in Table 1.

Table 1. Design Experiment

Group	Treatment	Post-test
Experimental	X	O_1
Control	-	O_2

The sampling technique uses purposive sampling, a sample selection method based on research criteria and considerations (Sugiyono, 2023). Sampling was based on the standard deviation of the average test scores of students, which then constructed class X-6 as an experimental group with ARCS learning model intervention assisted by brainstorming, while class X-8 was the control group that received instructional treatment based on discovery learning assisted by brainstorming.

The research variables consist of independent variables, namely the Attention, Relevance, Confidence, Satisfaction (ARCS) learning model assisted by brainstorming, and dependent variables, namely critical thinking skills.

This study implemented two types of data collection instruments: test-based and non-test-based. The test instrument was presented in the form of a descriptive assessment consisting of six items, all indicators of which comprehensively represent critical thinking skills. The instrument was implemented using the Cronbach's alpha formula, which aims to assess the extent to which the instrument produces consistent results. The Cronbach's alpha formula is as follows:

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

Description:
r_{11} : Reliability coefficient
k : Number of questions
$\sum \sigma_i^2$: Total variance of each item score
σ_t^2 : Total score variance

Meanwhile, the non-test instrument is realized in the form of an observation sheet for the implementation of the ARCS learning model syntax integrated with brainstorming techniques, which functions as an evaluative tool to review the suitability of the implementation of learning interventions procedurally.

Measuring student success in achieving critical thinking skills is done using the following formula:

$$P = \frac{n}{N} \times 100\% \quad (2)$$

Description:
P: Percentage of skill score (%).
n: Total score obtained by the student.
N: Maximum expected total score.

The scores obtained are then categorized according to each indicator. The assessment categories are shown in Table 2.

Table 2. Classification of Percentage of Critical Thinking Skills

Score Interval (%)	Category
$81,25 < x \leq 100$	Very High
$71,50 < x \leq 81,25$	High
$62,50 < x \leq 71,50$	Moderate
$43,75 < x \leq 62,50$	Low
$0 < x \leq 43,75$	Very Low

Source: Normaya (Delina, 2021)

RESULTS AND DISCUSSION

Results

This research was conducted in the pedagogical context of the experimental class using the ARCS learning model combined with brainstorming techniques. The control class implemented the discovery learning model, also integrated with brainstorming facilitation. The statistical data representation of the posttest results is compiled in Table 3.

Table 3. Posttest Statistical Data of Research Results

Statistical Data	Class	
	Experimental	Control
Number of Students	36	36
Ideal Score	150	150
Highest Score	145	110
Lowest Score	110	87
Mean	126,83	100,83
Variance	105,48	36,00
Standard Deviation	10,27	6,00

The statistical data presented in Table 3 shows that if students are able to answer all questions correctly, the maximum or ideal score that can be obtained is 150. The variation in posttest results is reflected in the range of highest to lowest scores. In the experimental class, the highest score achieved was 145 and the lowest score was 110, while in the control class, the highest score only reached 110 and the lowest score was 87. This disparity reflects the difference in cognitive performance between the two groups, especially in the context of mastery of critical thinking skills. In addition, the average score for the experimental class was 126.83 and the control score was 100.83. From these average scores, there is no overlap between the two classes because the experimental class has a range of 116-140 and the control class has a range of 95-111.

In the study, posttest data were obtained after each class was treated with different learning models. Hypothesis testing in the analysis of critical thinking skills involves two main stages: prerequisite testing and hypothesis testing. In the prerequisite testing stage, a series of statistical tests are conducted to ensure the basic assumptions required before conducting the hypothesis test are met, including: (1) normality test, which aims to examine whether the data distribution is in a normal distribution, and (2) homogeneity test, which is used to determine the similarity of variance between the groups being compared.

The first analysis is the normality test which is carried out using the chi-square test with the hypothesis: If X^2count < X^2table then H_0 is accepted and Ha is rejected, and if X^2count > X^2table then H_0 is rejected and Ha is accepted. The results of the calculation analysis regarding the normality test are shown in Table 4.

Table 4. Normality Test Data

Group	X^2count	X^2table	Conclusion
E	10,62	12,83	Normally Distributed
C	1,32	12,83	Normally Distributed

Referring to the results obtained, the X^2_{table} value is 12.83, while all X^2_{count} values generated from each data group in both classes are below the limit value. Thus, it can be concluded that the data from all groups come from a population that follows a normal distribution, so the normality assumption is met and the data is suitable for use in further parametric statistical analysis.

The next analysis is the homogeneity test, which is conducted to analyze whether the variance of the two classes' data is homogeneous or not. The homogeneity test method used is the Fisher test with the hypothesis that if $F_{count} < F_{table}$ then H_0 is accepted which means the variances are the same or can be said to be homogeneous and if $F_{count} > F_{table}$ then H_0 is rejected which means the variances are different or can be said to be not homogeneous. The results of the analysis of non-homogeneous data are shown in Table 5.

Table 5. Homogeneity Test Data

F_{count}	F_{table}	Conclusion
2,39	1,77	Data is not homogeneous

The results obtained regarding homogeneity showed that the F_{count} value of 2,39 exceeded the F_{table} value of 1,77, $F_{count} > F_{table}$. Therefore, it can be concluded that the variance of the posttest data between the experimental and control classes is not homogeneous, or in other words, the two data groups have variances that are statistically significantly different. This finding indicates that the homogeneity assumption is not met, so further hypothesis analysis needs to use a statistical approach that is appropriate to conditions of unequal variances, such as the t-test with the assumption of non-homogeneous variances (separated variances). The results of data processing from the inferential analysis using the t-test against the research hypothesis are presented in Table 6.

Tabel 6. Hypothesis Test Data

t_{count}	t_{table}	Conclusion
13,13	1,68	H_a is accepted and H_0 is rejected

The calculation of the hypothesis test listed in Table 6 shows a significant level ($\alpha = 0{,}05$) obtained $t_{count} > t_{table}$ which is 13,13 > 1,68 so that Ha is accepted and H_0 is rejected. Therefore, the 95% confidence level can be concluded that the Attention, Relevance, Confidence, Satisfaction (ARCS) learning model assisted by brainstorming has an effect on students' critical thinking skills on alternative energy material in class X of SMAN 1 Cihaurbeuti in the 2024/2025 academic year.

Discussion

This study shows that the application of the ARCS model assisted by brainstorming not only provides improvements in critical thinking skills indicators, but also shows a consistent pattern that is in line with the findings of previous studies. Compared to Ardiansyah (2018), who found that brainstorming was effective in improving critical thinking skills through collaborative idea exploration, this study confirms that strengthening motivation through the ARCS component magnifies this impact. This finding also aligns with Siregar (2025) report, which states that increasing learning motivation directly influences cognitive activation and improves students' critical thinking skills.

The first indicator is basic clarification or providing a simple explanation, which obtained a percentage of 87.13%. In this indicator, students explain phenomena concisely, clearly, and logically using their own understanding. This is in line with the findings of (Yasha, 2023) who stated that the use of phenomena or a contextual approach helps students understand the real picture of the events being studied, so that concepts are easier to internalize. This effectiveness is strengthened through the attention syntax in the ARCS model, which in this study is realized through the presentation of the roller coaster phenomenon as a learning stimulus.

The second indicator, building basic skills related to syntax relevance, achieved a learning percentage of 83.15%. In this indicator, learning emphasizes the relevance of material to everyday life contexts. This aligns with the findings of Karabatak and Polat in Hamidah et al., (2022), who showed that material linked to students' experiences and conditions, as well as providing contextual questions, significantly contributes to reasoning skills. This type of learning trains students to analyze situations and solve problems logically, while also encouraging them to collect and organize information systematically.

Figure 1. Roller Coaster Phenomenon

At this stage, information retrieval and classification activities strengthen the process of forming initial knowledge, in accordance with the principles of constructivism. The information obtained is not only understood but also used as a basis for analysis in PhET simulation practicums. The integration of information retrieval and verification through experiments demonstrates that students are beginning to apply concepts analytically, rather than simply repeating the material. The following image shows an experiment on energy on a skateboard.

In the PhET Skate Park experiment, students observe the changes in gravitational potential energy and kinetic energy that occur when a skateboard moves along a track. This activity introduces the basic concept of conservation of mechanical energy. However, to address the limited focus on physics content, particularly regarding alternative energy, this experiment can be expanded by relating the principle of energy transformation to the energy conversion mechanisms in renewable energy systems. The conversion of potential energy to kinetic energy on a skateboard can be viewed as a simple representation of the energy conversion process in alternative energy technologies.

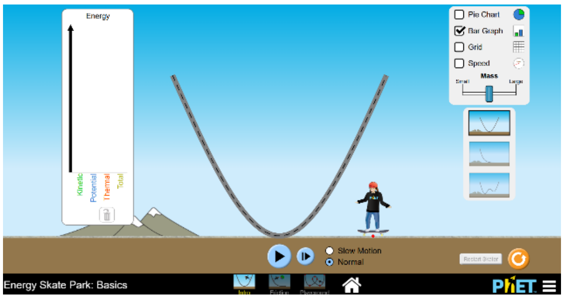

Figure 2. Energy experiments on skateboards

When the skateboard is at the highest point on the track, its potential energy is at its maximum, similar to the energy stored in water in a dam before it drives a turbine in a hydroelectric power plant (PLTA). As a skateboard descends a track, the potential energy is converted into kinetic energy, analogous to the movement of water turning a turbine to generate electricity. A similar principle exists in wind power plants (PLTB), where the wind's kinetic energy is converted into mechanical energy and then into electrical energy, and in solar power plants (PLTS), which convert solar radiation energy into electrical energy.

By integrating the context of alternative energy into the analysis of the experimental results, students gain a more comprehensive understanding that the energy changes, storage, and conversion they observe on a skateboard are universal physical principles and serve as the foundation for the development of renewable energy technologies. This approach not only strengthens mastery of the concept of mechanical energy but also increases the relevance of learning to energy sustainability issues and their real-life applications.

The third indicator, drawing conclusions, achieved a learning percentage of 85.37%. This indicator demonstrates students' ability to draw conclusions based on data verification and digital simulations, which can improve student evaluation. The PhET simulation in this study played a crucial role in facilitating evidence-based reflection. This activity was reinforced by confidence syntax, which aims to build student confidence in understanding and solving learning problems.

The fourth indicator is providing further explanations, which achieved a percentage of 82.31%. This indicator shows that students are able to develop logical inferences by conducting intergroup presentations, which enhance argumentative abilities and critical thinking skills. Furthermore, this indicator is supported by the syntax of confidence according to Keller in Jamil (2019) which explains that confidence is related to self-confidence, belief in achieving success, and positive expectations regarding learning outcomes and critical thinking.

The fifth indicator, the ability to organize strategies and tactics, showed an achievement of 84.44%, indicating that students were able to formulate work steps in a focused manner and practice developing experimental procedures that could develop scientific thinking patterns. Thus, this indicator shows that students have moved towards strategic thinking, marked by the ability to plan experimental steps logically and in a focused manner.

There were several limitations in implementing this research. One was the relatively short intervention time because it overlapped with the break schedule, necessitating additional adjustments to maintain conditions and create an optimal learning environment. Furthermore, the integration of the physics context was not carried out in depth and with variety, particularly in linking the material to real-world phenomena relevant to everyday life.

CONCLUSION

As a result of a series of research activities that include the process of data collection, processing, analysis, and hypothesis testing, it was concluded that the application of the ARCS learning model combined with the brainstorming strategy had a significant influence on improving students' critical thinking skills on alternative energy material in grade X in the even semester of the 2024/2025 academic year. This was proven by the achievement of a very high percentage of each indicator of critical thinking skills, which implicitly represents the success of pedagogical interventions in escalating the stimulation of higher-order thinking skills during the learning process in an intentional and systemic manner.

Based on the limitations of this study, the researcher suggests that future learning should present more interesting phenomena that are relevant to everyday life, not just one phenomenon, so that it can be more effective in arousing curiosity, increasing learning motivation, and attracting students' attention more broadly. In addition, further research is expected to develop the application of the Attention, Relevance, Confidence, Satisfaction (ARCS) learning model assisted by brainstorming on different topics or with variations of other collaborative strategies.

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