

STEM 4.0 APPROACH TO STRENGTHEN ADAPTIVE STUDENT CHARACTER

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Abstract

The purpose of this study was to determine the effectiveness of the STEM 4.0 approach in increasing CT which included differences in CT in experimental and control class students and in increasing student CT. The research method used is Quasi-Experimental Design with One Group Pretest-Posttest. This research involved 56 university students. The sample was treated in the form of learning with the STEM approach. Student CT includes 5 indicators, namely: (1) Interpreting Problems, (2) Analyzing Solution of the Problem, (3) Applying Gained Solution, (4) Evaluating the Gained Solution, and (5) Concluding the Results Attached with Supportive Evidence. The results of the study prove that based on the results of the Independent T-Test, there are significant differences in students' CT in the STEM class and the conventional class. The increase in CT in the experimental group was also significant based on the results of the Paired Samples Test. Thus, it can be concluded that the STEM 4.0 approach facilitates students to master the concepts of learning materials (Science) with the help of technology (Technology) and is strengthened by the application of these concepts in making simple products (Engineering). In addition, concept mastery is also supported by linking environmental phenomena in learning (Mathematics). The implementation of STEM 4.0 is effective in improving CT.

Abstrak

Tujuan penelitian ini yaitu untuk mengetahui efektivitas pendekatan STEM 4.0 dalam meningkatkan CT yang meliputi perbedaan CT siswa kelas eksperimen dan kontrol serta peningkatan CT siswa. Metode penelitian yang digunakan yakni Quasi-Experimental Design with One Group Pretest-Posttest. Penelitian ini melibatkan mahasiswa perguruan tinggi yang berjumlah 56 orang. Sampel tersebut diberi perlakuan berupa pembelajaran dengan pendekatan STEM. CT mahasiswa mencakup 5 indikator, yaitu: (1) Interpreting Problems, (2) Analyzing Solution of the Problem, (3) Applying Gained Solution, (4) Evaluating the Gained Solution, dan (5) Concluding the Results Attached with Supportive Evidence. Hasil penelitian membuktikan bahwa berdasarkan hasil Independent T-Test, terdapat perbedaan yang signifikan CT mahasiswa pada kelas STEM dan kelas konvensional. Peningkatan CT pada kelompok eksperimen juga signifikan berdasarkan hasil Paired Samples Test. Dengan demikian, dapat disimpulkan bahwa Pendekatan STEM 4.0 memfasilitasi mahasiswa untuk menguasai konsep-konsep materi pembelajaran (Science) dengan bantuan teknologi (Technology) dan diperkuat dengan penerapan konsep-konsep tersebut dalam membuat produk sederhana (Engineering). Selain itu, penguasaan konsep juga didukung mengaitkan fenomena lingkungan dalam pembelajaran (Mathematics). Penerapan STEM 4.0 efektif dalam meningkatkan CT.

## INTRODUCTION

Strengthening character has recently become a concern of the government in building superior Human Resources in higher education (Junaidi, 2020). This superior character can be formed with the freedom to learn through online learning, both inside and outside the faculty. This allows students to gain the knowledge they need to develop their potential. In addition, this freedom also trains students to have a fighting spirit and never give up on gaining knowledge. As a result, students will feel that there is still a lot of knowledge that needs to be achieved along with the more learning they get outside the study program. In the end, students will realize that they have to be lifelong learners to survive in every era of development.

Strengthening the character of these students is assessed related to Critical Thinking (CT). To concentrate on evaluating an issue and dealing with diverse obstacles (Anazifa & Djukri, 2017; Khasanah et al., 2017; Putra et al., 2018), CT is one of the most important abilities for students in the 21st Century (Rotherham & Willingham, 2010). Analyzing and locating numerous alternate solutions to issues is simple, allowing for the eventual discovery of the greatest option (Kaddoura, 2011). Therefore, having this talent is crucial, given that the challenges students will encounter are always expanding along with technological advancements and societal conditions (Mutakinati et al., 2018). Thus, it will be simpler for the student to analyze and describe a new problem or phenomenon based on the knowledge that has been understood through scientific procedures, where students are taught to think critically at each step to identify each core problem from these steps (Ramos et al., 2013).

Students must be able to articulate issues and locate potential solutions using accepted scientific practices to succeed in CT. As a result, CT needs to be taught as early as possible so that students can develop into trustworthy problem solvers and decision-makers based on critical thinking (Shernoff et al., 2017) when identifying problem points in each scientific procedure. Universities must develop an innovative learning environment so that there is a positive paradigm shift from teaching to learning where students are actively engaged in complex thought processes, taking into account the fact that CT is not passed down from generation to generation (Bustami & Corebima, 2017; Karim et al., 2018).

Furthermore, Teacher Training and Education students are prospective educators in

formal education. CT is very important for prospective educators to provide quality and meaningful learning. Moreover, the learning material conveyed is Natural Science where the scientific discipline is born from phenomena that occur in nature. With CT, prospective educators can present facts in everyday life that are integrated with learning materials to strengthen conceptual knowledge that must be mastered by students (Arends, 2012) so that students' understanding will be more profound and applicable.

Research on CT has been done. One of the research findings points to an urgent need to revise and design a curriculum that includes multiple activities (Bećirović et al., 2019). In addition, other studies have also revealed that the use of technological resources can improve student CT (Pauca-Curasma et al., 2023). The increase in CT will be more significant if teachers facilitate students with varied activities, not just the use of technology. Thus, it is necessary to innovate learning activities that encourage the achievement of critical thinking skills. One alternative solution is the application of the STEM 4.0 approach in learning.

The STEM 4.0 Approach is the best teaching strategy for the modern digital age and can improve CT. The STEM approach enables the incorporation of scientific disciplines based on the connection between learning materials and actual phenomena so that learning is meaningful and combined with science and mathematics so that a technical design is formed to develop technology (Moore et al., 2014). By carrying out an integrated experiment using learning media based on Information and Communication Technology (ICT) (Technology) and real materials, The STEM 4.0 approach helps students to grasp certain topics (Science) in groups.

Additionally, activities that use a STEM approach to learning aid students in developing additional 21st-century skills, particularly in collaboration and teamwork. By translating ideas into mathematical formulae, students can also learn to increase the efficacy of their work and the efficiency of the resources used (Mathematics). In the end, students can produce simple products (Engineering) that can be applied as learning media at school or useful to support daily life. Combining these four elements enables students to develop the skills to finish tasks and resolve real-world issues (Wang et al., 2011).

According to the description given, this study aims to evaluate the implementation of the STEM 4.0 strategy in science instruction to enhance student CT. Consequently, the following is a statement of the research question 1) Are there any differences in student CT in STEM and conventional classes?; and 2) Can STEM improve student CT?

## METHODS

### *Research Design*

This study uses a Quasi-Experimental Design with One Group Pretest-Posttest Design (Fraenkel et al., 2012). This study involved two classes. The experimental class was one of the two courses that received STEM 4.0 instruction for eight meetings. While the other 1 class does not use this approach (conventional learning) which is called the control class. Participants in both groups were given a CT test at cognitive levels C4 - C6 before and after the study. Learning is carried out on science material. This research was conducted in the Even Semester of the 2021-2022 Academic Year.

### *Research Sample*

The research sample consisted of 2 classes, which were determined using purposive sampling. The sample of this research is the students of Semester V Class A (as an experimental class) and B (as a control class) at one of the state universities in Lampung Province. The number of students in each class is 28 people.

### *Research Instruments and Procedures*

The CT test instrument is a description test with cognitive levels C4 (Analysis) and C6 (Creation) according to Bloom's Taxonomy (Conklin, 2005). The test instrument consists of 5 CT indicators. Each indicator is represented by 1 question description. The validity of this test instrument begins with construct validity, which is compiling indicators based on a literature review on CT. The 5 CT indicators are indicators developed by (Seventika et al., 2018), namely: (1) Interpreting Problems, (2) Analyzing Solution of the Problem, (3) Applying Gained Solution, (4) Evaluating the Gained Solution, and (5) Concluding the Results Attached with Supportive Evidence. Before being tested to continue the construct validity process, this instrument has also undergone an expert judgment process. 2 experts validated the test

instrument to test the instrument's feasibility in measuring CT in science material. The instrument has a score of 3.75 and is deemed valid based on the validation results.

The test data was analyzed with the Rasch Model using the application Winsteps version 3.73 to evaluate the instrument's validity and reliability. With a score of 0.379, 0.515, 0.571, 0.412, and 0.415 (higher than the value of  $r_{table} = 0.291$  for  $N = 44$ ), the instrument passed statistical tests and was deemed valid. Along with being deemed legitimate, the instrument has a Cronbach's Alpha rating of 0.666.

This instrument was given to participants before and after giving treatment. In learning, participants in the experimental class carry out learning activities that refer to 4 STEM components, namely Science, Technology, Engineering and Mathematics. Activities to understand the concept of learning materials to fulfill the Science Component. In understanding the concept, assisted by technology is the fulfillment of the Technology Component. With mastery of concepts, participants make simple tools that fulfill Engineering Components. Using numbers and formulations as well as reasoning during the learning process, is the fulfillment of the Mathematics Component.

### *Data Analysis*

The research data were analyzed statistically. The tests carried out were normality tests and data homogeneity tests as prerequisite tests for further tests. The Independent T Test and the Paired Samples Test come after the data have been deemed normal and homogeneous. The experimental and control classes were compared using the Independent T-Test to see if there were any variations in student CT. The increase in student CT after using the STEM 4.0 approach is measured through paired samples testing.

## FINDINGS AND DISCUSSION

### *Findings*

Based on statistical tests, it was found that the pretest data were normally distributed both in the experimental class and in the control class. This is indicated by the value of Sig. greater than 0.05 (Table 1). The same thing also happened to the posttest data in both classes where the value of Sig. greater than 0.05 (Table 2) which indicates that the data is normally distributed.

Table 1. Data of Normality (Pretest)

		Tests of Normality			Shapiro-Wilk		
		Kolmogorov-Smirnov <sup>a</sup>					
	Class	Statistic	df	Sig.	Statistic	df	Sig.
CT	Experiment	.100	28	.200 <sup>*</sup>	.955	28	.268
	Control	.097	28	.200 <sup>*</sup>	.970	28	.589

Source: Research data, 2022

Table 2. Data of Normality (Posttest)

		Tests of Normality			Shapiro-Wilk		
		Kolmogorov-Smirnov <sup>a</sup>					
	Class	Statistic	df	Sig.	Statistic	df	Sig.
CT	Experiment	.120	28	.200 <sup>*</sup>	.929	28	.059
	Control	.110	28	.200 <sup>*</sup>	.947	28	.163

Source: Research data, 2022

The next statistical test is the homogeneity test. Based on the test results, obtained the value of Sig. of 0.210 (Table 3), greater than 0.05. This indicates that the data

have the same variance between the experimental and control classes (homogeneous).

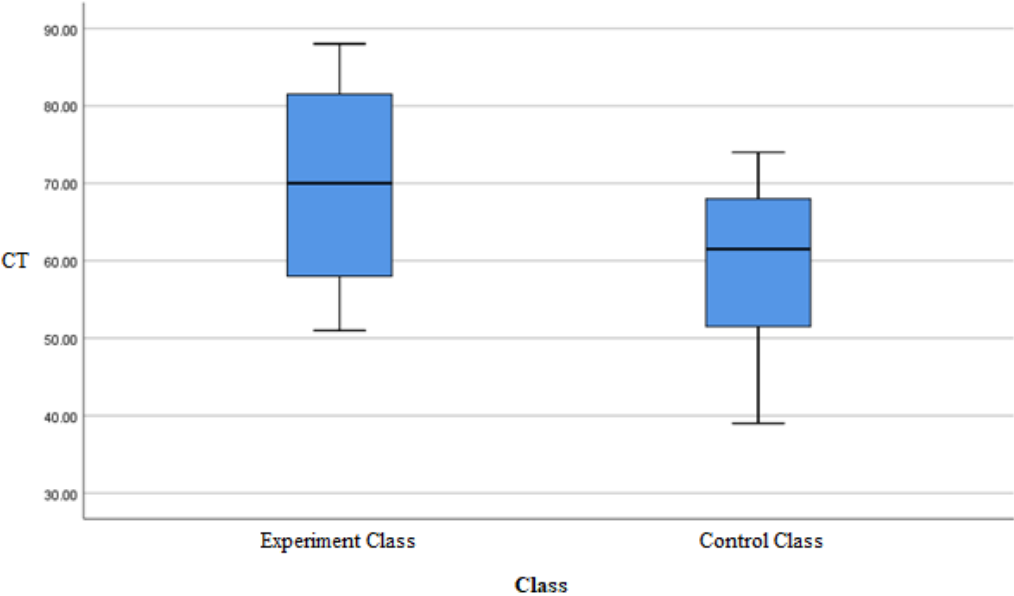
Table 3. Data of Homogeneity

		Test of Homogeneity of Variances			
		Levene Statistic	df1	df2	Sig.
CT	Based on Mean	1.607	1	54	.210
	Based on Median	1.601	1	54	.211
	Based on Median and with adjusted df	1.601	1	53.907	.211
	Based on trimmed mean	1.662	1	54	.203

Source: Research data, 2022

In addition, the Stem-and-Leaf Plots Diagram presented in Figure 1. The diagram shows that there are no Outliers. Therefore, it can

be continued to the next test, namely the Independent T Test.



Source: Research data, 2022

Figure 1. Stem-and-Leaf Plots of Posttest in Experiment and Control Class

Based on the Independent T Test results on the experimental and control class posttest data, the Sig. (2 tailed) or p value of 0.001 where < 0.05 (Table 5). Thus, it can be stated that the difference is statistically significant or significant at a probability of 0.05. The magnitude of the difference is shown in the Mean value of the two classes, which is 10.07143 (Tables 4 and 5). Because it is positive, it means that the experimental class has a higher mean than the control class.

Table 4. Data of Statistical Test

	Class	N	Mean	Std. Deviation	Std. Error Mean
CT	Experiment	28	69.3929	11.96396	2.26098
	Control	28	59.3214	9.83965	1.85952

Source: Research data, 2022

Table 5. Data of Independent T Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
CT	Equal variances assumed	1.607	.210	3.440	54	.001	10.07143	2.92743	4.20229	15.94056
	Equal variances not assumed			3.440	52.060	.001	10.07143	2.92743	4.19728	15.94558

Source: Research data, 2022

Furthermore, Paired Samples Test was conducted on the pretest and posttest data in the Experimental class. Based on the test results, obtained the value of Sig. (2-tailed) = 0.000 (Table 6). There is a difference between before and after treatment (Sig value or p value <0.05). Additionally, a positive Mean value of 38.68 is achieved. This indicates that there is an average 38.68 percent enhanced CT after treatment.

Table 6. Data of Paired Samples Test

		Paired Differences							
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	Sig. (2-tailed)
					Lower	Upper			
Pair 1	Pretest - Posttest	-38.67857	23.17894	4.38041	-47.66643	-29.69072	-8.830	27	.000

Source: Research data, 2022

Furthermore, the comparison of each student's CT indicator scores in the pretest and posttest in the experimental class can be seen in Figure 2. In the pretest, the highest score is in the Applying Gained Solution Indicator. However, this indicator is at the lowest score on the posttest score. While the lowest value in the pretest is in the Indicator Concluding the Result Attached with Supportive Evidence. In the posttest, the highest score is on the Interpreting Problems Indicator.

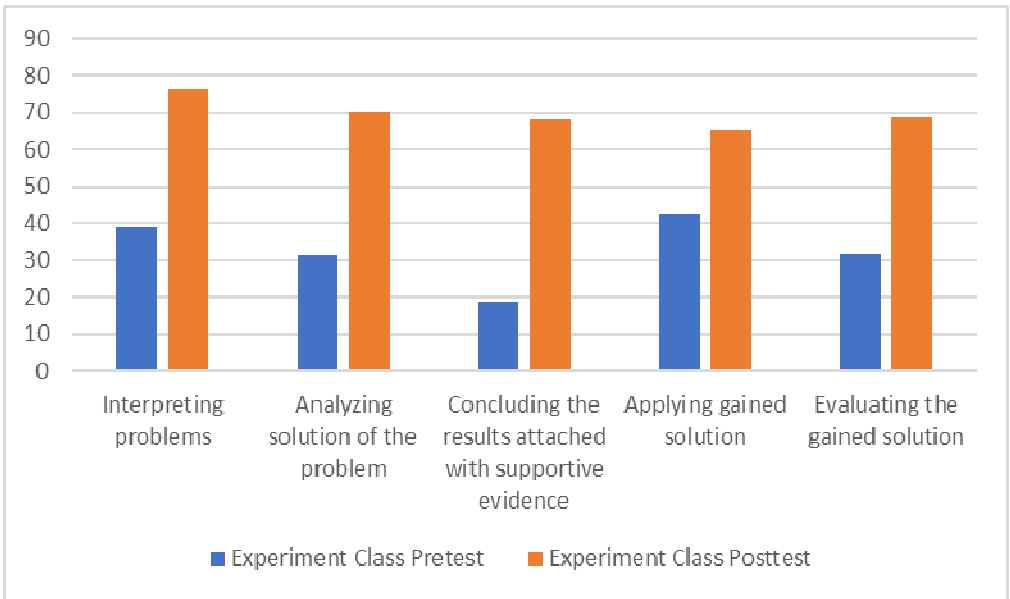


Figure 2. Pretest and posttest scores on each CT indicator in the Experimental Class  
Source: Research data, 2022

Comparison of n-Gain CT students can be seen in Figure 3 below. Based on the figure, the increase in the CT scores of students in the experimental class was higher than in the control

class on all CT indicators. Nevertheless, the Applying Gained Solution Indicator had the lowest increase in both the experimental and control classes.

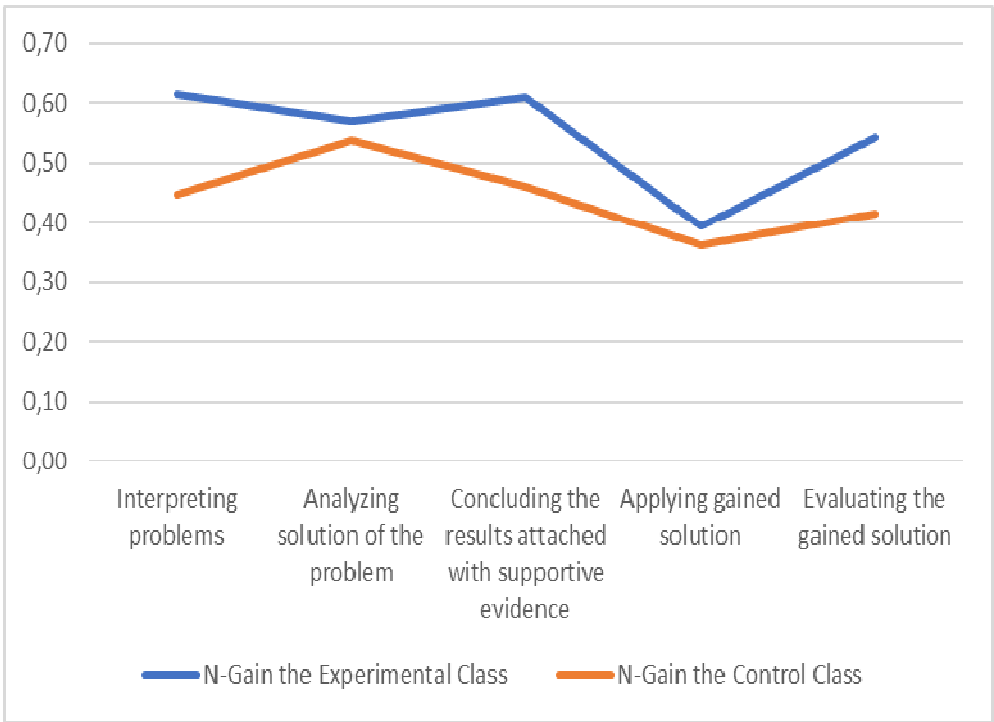


Figure 3. n-Gain Value in Experiment Class and Control Class  
Source: Research data, 2022

## Discussion

Learning with the STEM 4.0 Approach is carried out on science material online. The STEM 4.0 approach includes four components: Science, Technology, Engineering, and Mathematics. The purpose of Science here is the concepts contained in science learning materials. Technology is all tools used to make it easier for students to understand science concepts. In this study, researchers used learning videos containing simulations or recordings of events related to learning materials. Engineering is a simple product manufacturing process carried out by students based on the concepts learned. Mathematics is the application of mathematics related to numbers and calculations and reasoning or logic in linking material concepts to real life.

The main difference between learning with the STEM 4.0 Approach and conventional learning lies in the Engineering Component. The other 3 STEM components are implemented with not too much difference. In Component Engineering, students make simple products individually. Making this simple product begins with the distribution of learning materials that have been mapped out previously. Completion of the product is carried out for 2 weeks. Engineering as part of STEM is proven to have improved student performance in learning (Ting et al., 2022).

The learning process is carried out so that students can deepen their understanding of the concept of science material. This is because the STEM 4.0 approach trains students to develop cognitive and psychomotor abilities through the manufacture of simple products, which is a positive impact of the integration of 4 disciplines (Khwaengmek & Faikhamta, 2023). Students who understand the concept can make these simple products easily. This indirectly provides students an opportunity to prove that the concepts they learn are correct and can be used to support their daily activities (Ong, 2022). In addition, through this Engineering; students who do not understand the concept of guided material to connect the facts obtained during the manufacture of simple products so that students can master the concept as a whole.

### *Differences in Student CT in STEM Class and Conventional Class*

Based on statistical tests, there are differences in CT students who are taught with the STEM 4.0 approach and with conventional learning. This shows that the STEM 4.0 approach provides more benefits. The

combination of all components allows students to understand the concept of learning materials as a whole and in depth (Huffmyer et al., 2022). This familiarizes students to think scientifically accompanied by empirical evidence both provided in learning videos (Technology) and those obtained while manufacturing simple products (Engineering).

### *Improving Student CT in Learning with STEM*

The overall increase in student CT is quite high. However, the improvement in each CT indicator is quite variable. The highest increase was found in the Interpreting Problems Indicator. This is because this learning relates environmental phenomena to understand the concept of learning material which is the application of the Mathematics Component. The environmental phenomena in question are problems that need to be resolved. With a mechanism like this, students are accustomed to starting steps based on the correct data. Thus, it makes it easier for students to analyze the solutions to the problems found.

Furthermore, students can easily apply the obtained solutions. Moreover, students have also been trained through the process of making simple products which are the result of analysis of concepts and needs to support human activities. Nevertheless, the Applying Gained Solution Indicator has the lowest increase compared to the increase in the other 5 indicators. This is very reasonable because not all science material concepts can be applied to make simple products that support human activities. In this indicator, students still need to expand their experience related to the environment related to the concept of science material.

However, through the process of presentation and discussion in class; students have the ability to evaluate solutions obtained in virtual face-to-face forums (Tripon, 2022). Students give each other suggestions and input so that the best solution is obtained in solving problems, including also in improving simple products. In the end, students can conclude their work which is accompanied by supporting evidence.

## CONCLUSION

Based on the findings of the study and subsequent discussion, it can be said that the STEM 4.0 Approach to education aims to help students master the concepts of the subject matter (Science) through the use of technology (Technology) and that this goal is strengthened

by having students apply these concepts to the creation of straightforward products (Engineering). In addition, mastery of concepts is also supported by linking environmental phenomena in learning (Mathematics). In addition, the STEM 4.0 approach also significantly improves student CT.

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