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The Influence of the STEM-Based Engineering Design Process Model on High School Students' Creative and Critical Thinking Abilities

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Abstract: STEM-based Engineering Design Process learning model as a learning innovation to improve creative and critical thinking skills. This research aims to determine the influence of the STEM-based Engineering Design Process learning model on creative and critical thinking skills in a multivariate manner, as well as the correlation between students' creative and critical thinking skills on the subject of environmental pollution. The design of this research is Quasi Experimental with a pretest-posttest control group design. The treatment given to the experimental class was learning using the STEM-based Engineering Design Process model, while the control class used the Discovery Learning model with a scientific approach. The results of this research show that there is an influence of the STEM-based Engineering Design Process model on the ability to think creatively and critically in a multivariate manner with a value of sig. in Hotelling's trace from the MANOVA test 0.000 ‹ 0.05, and there is a correlation between creative and critical thinking abilities and the sig value. from the pearson test ‹ 0.000 ‹ 0.05. In conclusion, the STEM-based Engineering Design Process model is able to improve creative and critical thinking abilities, and there is a correlation between creative and critical thinking abilities.

Keywords: Creative thinking ability; Critical thinking ability; Engineering Design Process; STEM

Introduction

The 21st century is a century of globalization which is popular with the rapid development of science and technology. This has resulted in a change in the learning paradigm which is marked by changes in the curriculum, media and technology to support the learning process. One of the demands of 21st century learning is the integration of technology as a learning medium to develop students' learning skills (Rahayu et al., 2022). Therefore, the learning system in the 21st century has changed, which was previously teacher-centered, has now become student-centered. This aims to provide opportunities for students to be skilled in thinking and learning in the 21st century (Mardhiyah et al., 2021).

There are seven learning skills that need to be developed in the 21st century which are usually called the 7Cs, namely: Critical thinking and problem solving, Creativity and innovation, Collaboration, Cross-cultural understanding, Communication skills, Computing and ICT literacy (Computerization and ICT literacy), Carrer & learning self-reliance (Career and learning self-confidence) (Khoirunnisa & Habibah, 2020; Pratiwi et al., 2019). These skills can be trained through classroom learning activities. In the 5.0 era, it is proven that one of the basic skills needed by students is to utilize technology to solve problems faced through creative and innovative collaboration to face the digital era now and in the future (Wulandani et al., 2022). The skills discussed in this research are creative thinking skills and critical thinking skills.

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Creative thinking skills are an important aspect in creating and finding ideas to solve problems. The ability to think creatively can be trained in students to develop lots of ideas and arguments, ask questions, acknowledge the truth of arguments, and even make students able to be open in thinking and responsive to different perspectives (Khoiriyah & Husamah, 2018). The results of research from the 2015 International Trend of Mathematics and Science Study (TIMMS) stated that the level of creative thinking abilities of students in Indonesia is still lacking because only 0.4% of students in Indonesia can work on High International Benchmark type questions and 0.1% on High International Benchmark type questions. Advanced International Benchmark (Aryanti et al., 2021). High and advanced type questions are types of questions that require creative thinking skills to be able to find answers to solve the problems obtained.

Based on the 2015 Global Creativity Index (GCI) report, Indonesia is ranked 86th out of 93 countries in the Creative Class category and in the Global Creativity Index, Indonesia is ranked 115th out of 135 countries with an index of 0.202 (Lusiana & Andari, 2022). The lack of creative thinking skills in Indonesia is a basic problem that needs to be improved to meet the need for quality human resources. Apart from the ability to think creatively, it turns out that the ability to think critically is also very much needed in the 21st century. This is because someone who thinks critically will be able to think logically, answer problems well and be able to make rational decisions about what to do or what to believe.

Critical thinking is a high-level thinking skill that has the potential to increase students' analytical power. The results of the 2018 Program for International Students Assessment (PISA) study, Indonesia's science performance category was ranked 6th in the bottom among 79 countries with an average score of 396. Based on this data, Indonesia's performance appears to have decreased compared to the 2015 PISA report, where Indonesia ranks 69th out of 76 countries with an average score of 403 (Davidi et al., 2021). Science is one of the subjects that need to be given to all students so that they have the ability to think logically, analytically, systematically, critically and creatively as well as the ability to work together. The learning process implemented should be a forum for students to develop high-level thinking skills, especially critical and creative thinking abilities.

The reality in the field shows that students' creative and critical thinking abilities are still lacking. Based on the results of preliminary research conducted by researchers at one of Yogyakarta's high schools, it is known that of the 72 students in class X MIPA, only 20% were able to think creatively and 20% of students were able to think critically. This is because there is still a lack of training in creative and critical thinking skills during learning. Knowledge and skills are obtained when learning, most learning activities in schools still focus on knowledge, memory and reasoning. Learning activities that apply creative and critical thinking skills are able to produce something new in the form of ideas or real work.

The results of observations of biology learning regarding environmental pollution at one of Yogyakarta's high schools show that educators have not presented the real problems that exist around them. There are environmental problems, namely related to market waste. This is because the market renovation process is ongoing. Regarding this matter, a relocation place was created which of course was not as spacious and comfortable as the original location. The waste problem has not been properly managed so that if left unchecked it will pollute the surrounding community. Organic waste left over from vegetables from traders in the market is becoming more of a focus because it rots easily and causes an unpleasant odor. This problem should be raised in learning to train students' critical and creative thinking skills.

One way to overcome this problem is that innovation in learning is needed, namely using a STEM approach. The application of STEM in learning can encourage students to design, develop and utilize technology, sharpen cognitive, affective, and apply knowledge. STEM-based learning can train students to apply their knowledge to create designs as a form of solving problems related to the environment by utilizing technology to train high-level abilities so as to improve students' creative and critical thinking skills. The STEM approach can be applied in various ways. One model that can be used is the Engineering Design Process (EDP) as a basis for making connections between concepts and practices through mathematics or science or both (Blackley & Sheffield, 2015).

The EDP learning model involves combining engineering principles, analysis and systematic thinking (Triwulandari et al., 2022). Designing in EDP requires a thinking process that triggers students to be initiative and innovative, so that someone who designs will train their high-level thinking skills such as critical and creative thinking. The implementation of STEM-based learning through EDP involves students in the learning process directly, and invites students to plan activities involving technology to gain comprehensive knowledge (Widiastuti & Budiyanto, 2022). This means that students will apply more STEM knowledge and competencies in solving problems. Apart from that, there are several studies which say that STEM-based EDP can improve learning (Lin et al., 2021).

The results of other research reveal that EDP is an effective model in learning integrated with STEM for secondary students, because in the learning process it trains students to think scientifically (Tipmontiane & Williams, 2022). According to Putra et al. (2021) in their research, they explain that STEM-integrated EDP supports 21st century skills. This is because STEM-based EDP facilitates student collaboration through group work, where students can share and explore their ideas. In addition, students engage in argumentation in the planning, experimenting, and testing phases. Once students decide on their design to solve the problem, they carry out a self-check, looking at their design to see if the results are comparable to those of other groups. This situation demonstrates iterative thinking, which is one of the goals of effective critical and creative thinking.

Implementing STEM-based EDP in biology learning, teachers need to be careful in choosing material. Not all material, especially biology, can be taught through STEM, one of which is environmental pollution material which is new in this research. Environmental pollution material was chosen in this research because it is material that is full of the application of scientific knowledge, skills and attitudes. Apart from that, this material is very close to the everyday environment, making it easier for students to carry out analysis and think about design and technology related to this material. STEM-based EDP learning in this material has the potential to provide meaningful learning, it can train students' abilities to solve problems through projects that are integrated with several scientific fields such as science, engineering and technology.

Based on his description, researchers need to examine EDP activities using the STEM approach and their influence on overcoming problems regarding biology learning in high school with the title "Effectiveness of STEM-Based Engineering Design Process (EDP) Models on the Subject of Environmental Pollution on Students' Creative Thinking Abilities and Critical Thinking Abilities Class X High School”.

Method

Research Design

This research design is Quasi Experimental with pretest-posttest control group design (Creswell, 2014). The population in this study was all class X students at one of Yogyakarta's senior high schools, totaling 142 students. Sampling used a cluster random sampling technique, and two classes were taken, namely X MIPA I as the experimental class sample which applied the STEM-based EDP learning model, and The number of samples in each experimental and control class was 36 students.

Data Collection and Analysis Techniques

Research data was obtained from pretest-posttest scores. The pretest-posttest is in the form of short essay questions which are presented according to derivatives of creative thinking indicators from Torrance (Torrance, 2018; Kim, 2006; Alabbasi et al., 2022), namely: fluency, flexibility, and originality, and critical thinking indicators from Ennis (1996), namely: elementary clarification, basic support, inference, advanced classification, strategy and tactics. At the first meeting, students were asked to do pretest questions to find out their initial understanding regarding environmental pollution material. Then at the end of the meeting students were also asked to do posttest questions to find out the extent of students' understanding after learning using the STEM-based EDP model.

Data were analyzed using MANOVA to determine the influence of the STEM-based Engineering Design Process learning model on creative and critical thinking skills in a multivariate manner with pretest scores as a covariate. Meanwhile, to determine the correlation between research variables, it was analyzed using the Pearson test with a significance level of 5%. If the sig. < 0.05 means that there is a positive relationship between creative and critical thinking abilities. Meanwhile, if the sig value. > 0.05, then there is no relationship between creative thinking ability and critical thinking.

Data analysis in this study also used N-Gain scores as reinforcement for the MANOVA test. The calculation results are then interpreted using the N-Gain category according to Sugiyono (2012) which is presented in Table 1.

Table 1. N-Gain Value Category

N-Gain	Interpretation
$g \geq 0.7$	High
$0.3 \leq g < 0.7$	Medium
$g < 0.3$	Low

After carrying out the N-Gain test, the effect size test is then carried out. Effect size is a measure of the practical significance of research in the form of a measure of the magnitude of the correlation or difference, or the effect of one variable on another variable. The calculation results are then interpreted using categories according to Cohen (1988) which are presented in Table 2.

Table 2. Effect Size Category

Value Range	Interpretation
> 0.40	Very Stronge
0.26 – 0.40	Stronge
0.11 – 0.25	Medium
0.00 – 0.10	Weak

Result and Discussion

Descriptive analysis

Descriptive analysis of students' creative and critical thinking abilities includes analysis of initial ability data (pretest) and final ability data (posttest). The results of the descriptive analysis of pretest and posttest creative thinking abilities can be seen in Table 3.

Table 3. Results of the Pretest and Posttest Descriptive Analysis of Students' Creative Thinking Ability

Description	Pretest		Posttest	
	Experiment Class	Control Class	Experiment Class	Control Class
N	36	36	36	36
Maximum value	77	88	100	100
Min value	33	44	67	44
Standard deviation	10.890	14.429	10.222	14.204
Average	47.9	63.5	86.5	78.4

Based on the results of the descriptive analysis in Table 3, the average creative thinking pretest score between the experimental and control classes is not the same. The pretest score for the experimental class was 47.9 and the control class was 63.5. After being given treatment in the learning process regarding environmental pollution material, the experimental class used the EDP-STEM model and the control class used the Discovery Learning-scientific model, then given a posttest the average results increased compared to the pretest. The average posttest score for the experimental class was 86.5 and the control class was 78.4. The average posttest score for the experimental class was higher than the control class with a difference of 8.1. Apart from that, the results of the pretest and posttest descriptive analysis of critical thinking skills can be seen in Table 4.

Based on the results of the descriptive analysis in Table 4, the average critical thinking pretest score between the experimental and control classes is not much different. The pretest score for the experimental class was 63.4 and the control class was 67.6. After being given treatment in the learning process regarding environmental pollution material, the experimental class used the EDP-STEM learning model and the control class used the Discovery Learning-scientific model, then given a posttest the average results increased compared. The average posttest score for the experimental class was 86.6 and the control class was 74.3. The average posttest score for the experimental class was higher than the control class with a difference of 12.3.

Table 4. Results of Pretest and Posttest Descriptive Analysis of Students' Critical Thinking Ability

Description	Pretest		Posttest	
	Experiment Class	Control Class	Experiment Class	Control Class
N	36	36	36	36
Maximum value	80	80	100	93
Min value	40	60	73	40
Standard deviation	7.899	6.303	8.452	11.422
Average	63.4	67.6	86.6	74.3

To clearly understand the difference in average pretest and posttest scores on creative and critical thinking abilities, it can be seen in the diagram in Figure 1.

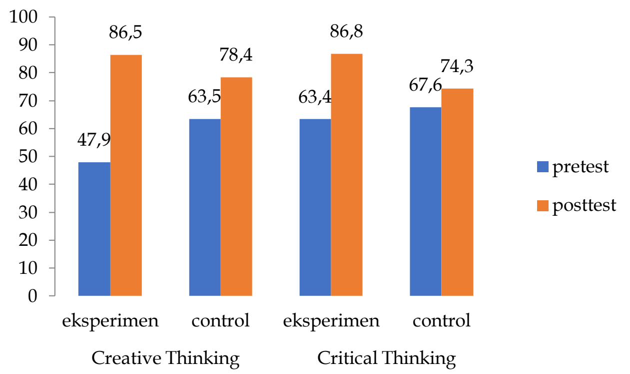

Figure 1. Diagram of the Average Pretest and Posttest Scores for Creative and Critical Thinking

Based on Figure 1, it can be said that the average pretest scores for the two classes have different results. Then, after being given treatment, the average posttest score in the experimental class was higher, namely using the EDP-STEM model, compared to the control class which used the Discovery Learning-scientific model.

Analysis Prerequisite Test

Data obtained from the research is in the form of pretest and posttest score data on creative and critical thinking. These values must meet the prerequisite tests first before being analyzed using multivariate MANOVA parametric calculations, the prerequisite tests are calculated from:

1. The two dependent variables are measured at the interval or ratio level.

2. The independent variable consists of two categories, the independent group, namely the experimental class using the STEM-based Engineering Design Process model and the control class using the Discovery Learning model with a scientific approach.
3. When making observations, you have independence of observation, which means there is no relationship between observations in each group or between groups.
4. Have an adequate number of samples, namely 36 samples in each experimental and control class.
5. There were no univariate or multivariate outliers. Based on the results of the analysis carried out using the SPSS program, the outlier test results were obtained using the Block Plot which are presented in Figure 2 and Figure 3.

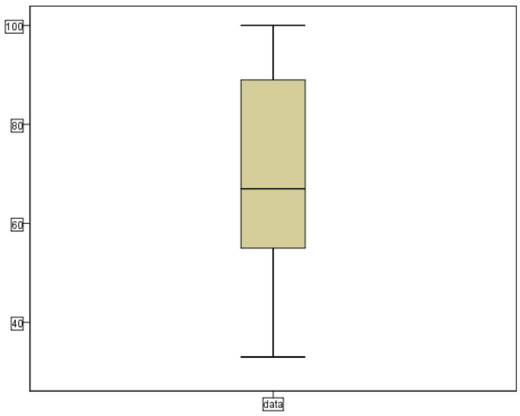

Figure 2. Creative Thinking Block Plot

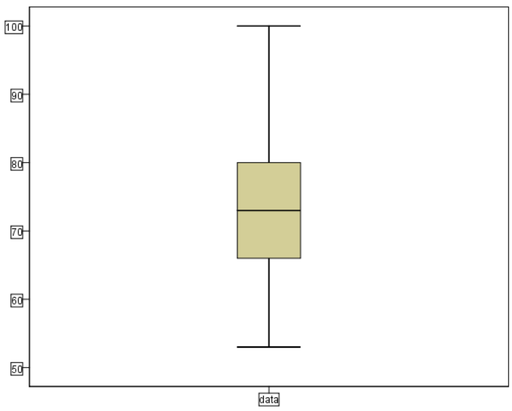

Figure 3. Critical Thinking Block Plot

6. Multivariate normality distribution data was carried out by making a scatter plot between the mahalanobis distance and chi square. If the correlation coefficient > r table / sig. < 0.05, then there is a significant correlation, so the data comes from a sample with a multivariate normal distribution. The results of the multivariate normality analysis are presented in Table 5.

Table 5. Results of Mahalanobis Multivariate Normality Analysis

Class	Mahalanobis Distance	qi	Information
Pretest experiment	Pearson Correlation	.952**	Multivariate Normality
	Sig. (2-tailed)	.000	
Posttest experiment	Pearson Correlation	.970**	Multivariate Normality
	Sig. (2-tailed)	.000	
Pretest control	Pearson Correlation	.945**	Multivariate Normality
	Sig. (2-tailed)	.000	
Posttest control	Pearson Correlation	.987**	Multivariate Normality
	Sig. (2-tailed)	.000	

Results of multivariate normality analysis using the mahalanobis test. Data on pretest-posttest scores for the experimental class and pretest-posttest for the control class obtained sig values. < 0.05, namely 0.000, so it can be concluded that the data comes from a sample with a multivariate normal distribution.

7. There is a linear relationship between pairs of dependent variables for each group of independent variables. Data from SPSS analysis are presented in Table 6.

Table 6. Linearity Test between Variables

			F	Sig.
Critical thinking * Creative thinking	Between Groups	(Combined)	1.310	.288
		Linearity	.553	.462
		Deviation from Linearity	1.688	.201

Obtained sig value. the deviation from linearity is 0.201 > 0.05 so it can be concluded that there is a linear relationship between variables.

8. There is homogeneity of the variance-covariance matrix. This assumption was tested by multivariate homogeneity analysis using SPSS, namely the Box's M test for equality of covariance which is presented in Table 7. Based on the results of the homogeneity analysis, it shows that the Box M value in the creative thinking ability data is 6.510 with sig. 0.092 > 0.05 and critical thinking ability data of 6.583 with sig. 0.089 > 0.05, so it can be concluded that the data from the two dependent variables are homogeneous.

Tabel 7. Box's M Homogeneity Results

		Test Results	
		Creative Thinking	Critical Thinking
	Box's M	6.510	6.583
F	Approx.	2.145	2.169
	df1	3	3
	df2	3.528E4	3.528E4
	Sig.	0.092	0.089

9. There is a correlation between creative and critical thinking abilities, proven by the correlation test presented in Table 10, showing that the sig. < 0.05.

Application of the EDP-STEM Model to Students' Creative and Critical Thinking Abilities

Based on the prerequisite test results, it is known that the nine assumptions or prerequisites for the MANOVA test have been fulfilled. So the next stage is analysis using MANOVA to find out how the EDPSTEM model influences creative and critical thinking abilities. The analysis results are presented in Table 8.

Tabel 8. Multivariate Analysis of Variance Test (MANOVA)

Effect	Value	F	Hypothesis df	Error df	Sig.
Pillai's Trace	.338	17.611[a]	2.000	69.000	.000
Wilks' Lambda	.662	17.611[a]	2.000	69.000	.000
Hotelling's Trace	.510	17.611[a]	2.000	69.000	.000
Roy's Largest Root	.510	17.611[a]	2.000	69.000	.000

In this study, two groups of independent variables were used so that decision making from the MANOVA test looked at the significance value in Hotelling's trace. Based on Table 8, it is known that the sig value. 0.000 < 0.05, which means there is an average difference in creative and critical thinking abilities between the experimental and control classes. So it can be concluded that there is an influence of the STEM-based Engineering Design Process (EDP) learning model on the creative thinking abilities and critical thinking abilities of class X high school students on the subject of environmental pollution. Next, an N-Gain test was carried out using SPSS to determine the increase in students' creative thinking scores before and after learning in the experimental class and control class which are presented in Table 9.

Tabel 9. Comparison of N-Gain Values and Effect Size

Criteria	N-Gain Score			
	Creative Thinking		Critical Thinking	
	Experiment	Control	Experiment	Control
Average	0.7250	0.3036	0.6438	0.1568
Min	0.35	-0.96	.21	-1.22
Maximum	1.00	1.00	1.00	.82
Effect size	0.57		1.5	

Based on Table 9, it is known that the average score in the experimental class is higher than the control class. The average N-Gain value for creative thinking in the experimental class was 0.7250, including the high category and in the control class, 0.3036, including the medium category. The average critical thinking N-Gain value in the experimental class was 0.6438, which was in the high category and in the control class, 0.1568, which was in the low category. From the average N-Gain value in the experimental and control classes, it can be concluded that the STEM-based Engineering Design Process (EDP) model in the experimental class has better effectiveness in critical thinking abilities when compared to the control class. Meanwhile, the effect size value for creative thinking ability was 0.57, which was in the very strong category, and the effect size value for creative thinking was 1.5, which was in the very strong category. It can be concluded that the application of the STEM-based EDP model has a significant positive influence on creative and critical thinking abilities as the dependent variable in this research.

Efforts to improve creative and critical thinking skills begin with analyzing critical thinking skills. Students' critical thinking abilities increase as a result of the learning process carried out. Learning was carried out over three meetings, where at the first meeting students were invited to analyze the causes and impacts of existing environmental problems, namely the problem of organic waste at the Godean market transit location. Then students are invited to think critically about how to overcome these problems. Problem-based learning encourages students to learn systematically, work with groups, and find solutions to improve their critical thinking skills (Narmaditya, 2018). Problem-based learning is able to stimulate critical thinking in situations involving real-world problems and allows students to adapt, adjust, change, or improve their thinking to make better decisions about what to do (Ayunda et al., 2013).

Critical thinking is a complex thinking ability that consists of providing simple explanations, building basic skills, concluding, making further explanations, and creating and designing tactical strategies (Ennis, 1996). There is an increase in students' critical thinking skills because during the learning process using the

EDP-STEM model, students are guided by the teacher to carry out investigations. The investigation stage will direct students to develop their critical thinking skills which are characterized by finding various problems in everyday life related to environmental pollution that occurs. Then analyze the factors causing the problem. The learning process is more effective and active in developing students' critical thinking skills when compared to the learning usually carried out by teachers, namely using the discovery learning model in the classroom (control class). Students' critical thinking will be trained when participants are actively involved (student center) (Yasifa et al., 2023).

Critical thinking abilities can be improved through various learning strategies (Saputri et al., 2019). The combination of the Engineering Design Process (EDP) model with a STEM approach teaches sustainable critical thinking through questions, lessons and activities that focus on higher levels of thinking abilities. We can also see students' critical thinking abilities through students' abilities in answering pretest and posttest questions. Based on data processing in Table 3, it is known that students in the experimental class have superior critical thinking skills compared to the control class. One of the factors that influence students to be less than optimal in answering critical thinking questions is because the questions are in the form of discourse so they require students to focus and analyze. Like research conducted by Suriati et al. (2021), there are students who are less careful in their work. To overcome this, Collins explains that teachers can teach HOTs continuously with various strategies such as: teach skills through real world contexts, vary the context in which students use newly taught skills, emphasize high-level thinking, build basic knowledge, classify categories, create hypotheses, make conclusions, analyze components, solve problems (Zubaidah, 2018).

Learning using a STEM approach is not only able to solve problems in the form of concepts, but also solve problems directly by implementing concepts into solutions that have been formulated (Marta, 2023). There is an increase in students' ability to think critically, followed by students' ability to think creatively. This is proven by students' decision-making actions to solve problems through designing a solution. Creative thinking skills are part of creativity, namely creating ideas and products to solve a problem (Zulyusri et al., 2023). According to Csikszentmihalyi (1997) creative thinking is the ability to think that produces new ideas within or across domains of knowledge, and actively involves students in gathering existing ideas into new configurations, and developing them.

There is an increase in the ability to think creatively, this is because in the experimental class using the EDP-STEM model students are trained to systematically find out and understand environmental pollution material through a discovery process that requires students to think creatively (Narmaditya, 2018). A systematic learning process through the EDP model where learning is centered on students being able to identify problems related to environmental pollution, solve problems, design solutions, test trials, and convey results independently with the group. Student-centered learning can provide opportunities for students to seek knowledge and solutions in solving problems that can improve students' creative thinking abilities (Ulandari et al., 2019).

Application of the EDP-STEM model as a learning innovation to improve creative thinking abilities. Chamberlin & Mann proved through their investigations that the teacher's learning approach is one of the important factors that can develop students' creativity. This shows that the creativity and readiness of teachers in applying modern learning models and approaches and in accordance with the needs and circumstances of students can improve students' thinking, one of which is creative thinking.

Learning needs to be attempted to balance scientific knowledge with the environment and technology. Through the simple process of making biogas, students can learn about science, manufacturing technology, engineering and mathematics. Considering the importance of creative thinking skills and mastery of technology, EDP learning is suitable to be integrated with a STEM approach. Saputri et al. (2019) revealed that the STEM approach with projects provides students with experience in solving real problems with practical activities, so that it can increase effectiveness and meaningful learning. One of the learning objectives using a STEM approach is to try to provide experience through investigative skills, problem solving, science skills, technology, innovative thinking skills through logical reasoning and creativity processes.

Through EDP-STEM learning, students can be trained to apply their knowledge to create designs that are able to solve environmental problems, and they can develop advanced skills in utilizing technology to improve high-level thinking abilities. At the second learning meeting, students were directed to design a solution to the organic waste problem that had been analyzed at the first meeting, namely by making simple biogas. The results of the student's design for making simple biogas can be seen in Figure 4 and Figure 5.

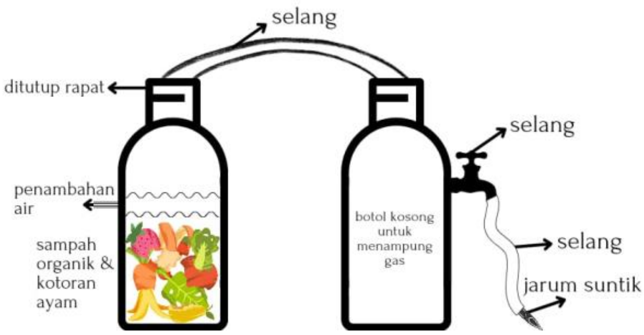

Figure 4. Design 1: Simple Biogas Design

Figure 5. Design 2: Simple Biogas Design

From the designs made by students in the picture above, it provides information that between groups of students has different creativity. Designing is an integral part of the STEM element as well as in the EDP model, namely "engineering" which requires a thinking process that triggers students to be initiative and innovative, so that through the design process they can train critical and creative thinking skills, including the high level thinking skills needed in the age of this globalization (Ulum et al., 2021). Engineering design is an alternative learning that helps improve positive attitudes, understanding, collaborative abilities and creativity to ensure the design of new and innovative products in solving problems by applying the use of science, mathematics and technology (Han & Shim, 2019). Li et al. (2019) explain that learning through the design process emphasizes creativity and innovation to encourage different perspectives and approaches in seeing and solving problems.

Making a simple biogas design is then realized in real life by students together in groups and tested. Of the two simple biogas designs, each group has its own advantages and disadvantages. Design 1 in Figure 4 emits a very small fire because the gas storage tube is the same size as the organic waste storage tube. So when the gas tap is opened there is less pressure from inside the tube. Design 2 at Figure 5 shows on the third day the balloon burst, then improvements were made by replacing the balloon with a thicker one and producing a good fire. These things are recorded by each group as material for analysis and evaluation which will be presented at the final learning meeting.

At the third learning meeting, students presented the results of trials of biogas products that had been designed. Students convey the advantages and disadvantages of the biogas product being designed, and other group participants are invited to provide suggestions and input. All learning steps are in accordance with the EDP model syntax starting from Define the problem, Learn about the problem, Plan a solution, Try a solution, Test a solution, to Decide whether the solution is good enough (Utomo et al., 2021). At the end of the lesson, the teacher reviews the material that was studied at the meeting to strengthen understanding of the concept. From this, teachers can also evaluate the extent to which students can absorb the material on environmental change and pollution studied (Akbar, 2021).

The EDP-STEM model is very suitable to be implemented in environmental pollution material by raising environmental problems around it (the accumulation of waste at the Godean transit market) and designing products as solutions to these problems. Not only formulating solutions, but students are trained to think critically by analyzing the causes of the accumulation of waste which causes environmental pollution with environmental quality standards. One of the causes is organic waste left over from vegetable sales which needs to be handled immediately. This problem requires students to be able to think creatively to come up with solutions through an engineering process which is a link between the EDP model and the STEM approach while still involving other EDP-STEM elements in the learning process.

The Relationship between Creative and Critical Thinking Abilities in the Application of the EDP-STEM Model

Tabel 10. Correlation Test of Creative and Critical Thinking Ability

Correlation Test Results		Creative Thinking	Critical Thinking
Creative Thinking	Pearson Correlation	1	.618**
	Sig. (2-tailed)		.000
Critical Thinking	Pearson Correlation	.618**	1
	Sig. (2-tailed)	.000	
	N	36	36

To determine the relationship (correlation) using the Pearson test which is presented in Table 10. The calculation results are then interpreted using the N-Gain category according to Ichsan et al. (2019) which are presented in Table 11.

Tabel 11. Interpretation of Correlation Values

Range of Correlation Values	Criteria
0.00 – 0.19	Very low
0.20 – 0.39	Low
0.40 – 0.59	Medium
0.60 – 0.79	High
0.80 – 1.00	Very high

The results of the correlation test obtained a sig value. from .000 < 0.05, which means there is a relationship or correlation between creative thinking abilities and critical thinking abilities. Interpretation of the relationship between the two dependent variables can be seen in the Pearson correlation value, which is 0.618, so it can be concluded that creative and critical thinking abilities have a strong relationship, and a positive Pearson value indicates that if one of the dependent variables increases, it will be followed by an increase in the other dependent variable.

There is a relationship between creative and critical thinking skills because in using the EDPSTEM model, learning is designed based on HOTS which is able to improve high-level thinking skills which include creative and critical thinking skills, through analysis that supports the achievement of success in achieving learning outcomes (Marta, 2023). Hots-based learning is very necessary in science and environmental learning. This is because many environmental problems can be solved with HOTS capabilities (Ichsan et al., 2019). HOTS is a thinking skill that not only requires the ability to remember but also other higher abilities including analyzing, evaluating and creating (Rosidin et al., 2019), which can be improved using the EDP-STEM model.

The learning process in the EDP-STEM model raises problems related to the material taught, namely environmental pollution material and must be discussed in groups. Students and their group friends can analyze, evaluate and create a product as a solution to existing problems. The activities carried out can increase students' understanding regarding the concept of environmental pollution, so that students can identify, formulate, look for several alternative solutions to problems and find the best solution.

This is in line with several studies that have been conducted. Based on research conducted by Usman et al. (2020), states that there is a relationship between students' critical and creative thinking abilities from a correlation coefficient value of 0.427 with medium criteria. Siswanto & Ratiningsih (2020) also explained that there is a relationship between critical and creative thinking abilities and problem-solving abilities which will improve the quality of the learning process. Apart from that, Mayarni & Yulianti (2020) also wrote that there is a relationship between students' critical thinking abilities and creative thinking abilities. Their critical and creative thinking skills can train students to reason logically through arguments, interpretation, evaluation, and being able to draw conclusions so that students are motivated to put forward new, unique ideas in solving a problem.

The ability to think creatively and critically is an integrated component of thinking which is the goal of national education. Both are said to be skills that must be possessed individually or in groups. The application of creative and critical thinking skills does not depend on difficult material. However, no matter how simple or difficult problems can lead students to achieve this goal (Samura, 2019).

Conclusion

The application of the STEM-based Engineering Design Process (EDP) model has a positive effect on the creative and critical thinking abilities of class X high school students on the topic of environmental pollution. There is a positive influence because the learning process is presented on a problem-based basis which is able to train students to implement learning concepts into solutions with decision-making actions to solve problems by designing a solution. In addition, based on the research results, there is a strong relationship between students' creative and critical thinking abilities in implementing the STEM-based Engineering Design Process (EDP) learning model for class X on the topic of environmental pollution. This is because learning designed with HOTS allows students to develop high-level thinking skills, such as creative and critical thinking skills, through analysis that supports the achievement of learning outcomes.

Authors Contribution

Data collection and analysis, W.S.; methodology, W.S. and S. S; validation, S.S.; original draft preparation, W.S; writing—review and editing, W.S., S.S., and W.W.P.

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Conflicts of Interests

The authors declare no conflict of interests.

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