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Integrating The STEM-DT Model to Enhance Students' Creative Disposition and Creative Products Through a Water Filtration Project

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ABSTRACT Education in the modern era requires students to have high creative skills to face the challenges of a complex world. However, the lack of teaching learning models that foster students' creativity is a common problem in classroom learning. This research aims to explore the impact of the STEM-DT (Science, Technology, Engineering, and Mathematics-Design Thinking) learning model on students' creative disposition and creative products. A quasi-experimental design was used, involving two groups: an experimental class using the STEM-DT learning model and a control class employing conventional teaching methods. The participants consisted of 52 junior high school students. Instruments included a creative disposition questionnaire and a rubric for evaluating creative products. Data were analyzed using t-tests, Cohen's d calculations, and N-Gain measurements. The results indicated a significant difference in average creative disposition between the control and experimental classes, with a t-test significance value of 0.040 and Cohen's d effect size of 0.586 (medium category). The average N-Gain score of creative disposition in the experimental class reached 0.1213, while in the control class, it was 0.0508, showing greater improvement in the experimental group. Additionally, the average creative product score in the control class was 48.89%, categorized as moderately creative, while the experimental class scored 84.07%, categorized as highly creative. The findings suggest that the STEM-DT learning model significantly enhances students' creative disposition and the quality of innovative products, providing essential preparation for younger generations to navigate the complexity and dynamics of global change.

Keywords STEM-DT, Creative disposition, Creative products, Water filtration

1. INTRODUCTION

Science education plays a crucial role in shaping a generation capable of tackling major future challenges. With rapid advancements in technology and science, science education is not only a means of understanding the natural world but also a foundation for creating innovations that positively impact human life. Therefore, science education must develop analytical skills, creativity, and problem-solving abilities relevant to real-world issues such as climate change, environmental pollution, and limited access to clean water (Baran, Baran, Karakoyun, & Maskan, 2021; Wan, So, & Hu, 2021).

Although science is already taught in schools, classroom learning often focuses excessively on theory, neglecting the connection between scientific concepts and everyday life. Consequently, many students struggle to apply their knowledge in real-world contexts (Diep et al., 2023; Hiwatig, Roehrig, & Rouleau, 2024; Sulaeman, Efwinda, & Putra, 2022). This highlights the need for teaching learning models that not only impart knowledge but also hone students' critical, creative, and innovative thinking skills (Nasri, Rahimi, Nasri, & Talib, 2021; Sawu, Sukarso, Lestari, & Handayani, 2023; Simeon, Samsudin, & Yakob, 2022).

Developing students' creative disposition is increasingly recognized as a primary goal of modern science education (Sawu, Sukarso, Lestari, & Handayani, 2023). Creative disposition encompasses not just the ability to generate new ideas but also attitudes, habits, and skills that drive innovative, adaptive, and transformative thinking (Sawu, Sukarso, Lestari, & Handayani, 2023; Suciani & Prima, 2020). Research indicates that creative disposition involves

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key dimensions such as openness to new experiences, willingness to take risks, curiosity, divergent thinking, and resilience in facing challenges (Baran, Baran, Karakoyun, & Maskan, 2021; Sawu, Sukarso, Lestari, & Handayani, 2023; Wan, So, & Zhan, 2023). Students with a strong creative disposition tend to be flexible in addressing problems, open to new perspectives, and willing to experiment with unconventional learning models.

Beyond intellectual abilities, creative disposition also encompasses emotional and psychological aspects that influence how students confront problems (Sawu, Sukarso, Lestari, & Handayani, 2023; Sukarso, Artayasa, Bahri, & Azizah, 2022). Those with strong creative dispositions are likely to see opportunities in challenges, remain undeterred by failure, and persist in seeking solutions despite difficulties. In a constantly changing world, such skills are invaluable not only for academic success but also for addressing increasingly complex global challenges.

Creative products often reflect the level of students' creative disposition. These products represent tangible manifestations of innovative thinking that combine deep understanding, unique ideas, and relevant solutions (Chien, Liu, Chan, & Chang, 2023; Puchongprawet & Chantraukrit, 2022; Sawu, Sukarso, Lestari, & Handayani, 2023). In science education, creative product quality is usually assessed through criteria such as originality, flexibility, the ability to solve complex problems, and the social and environmental impact (Suciani & Prima, 2020).

Creative product assessments include various criteria, such as solution originality, offered innovation, effective functionality, sustainable design, and practical implementation potential (Puchongprawet & Chantraukrit, 2022; Sawu, Sukarso, Lestari, & Handayani, 2023). High-quality creative products not only solve problems but also add real value through new, relevant, and applicable ideas (Chien, Liu, Chan, & Chang, 2023; Puchongprawet & Chantraukrit, 2022). Developing such products requires interdisciplinary thinking, systemic problem-solving skills, and sensitivity to societal or environmental needs. Moreover, the success of creative product development heavily depends on a supportive learning environment, the teacher's role as a facilitator, and opportunities for students to experiment and explore innovative ideas (Sawu, Sukarso, Lestari, & Handayani, 2023).

In an effort to meet these needs, the Science, Technology, Engineering, and Mathematics (STEM) learning model has emerged as a promising solution. STEM integrates various disciplines to help students understand and solve real-world problems (Guzey & Li, 2023; Han, Kelley, & Knowles, 2023). The application of STEM-based learning in enhancing several competencies has been discussed in numerous studies. STEM learning is capable of improving students' critical thinking skills and preparing them to solve problems more creatively (Han, Kelley, & Knowles, 2023). Other research also confirms that STEM learning can enhance student engagement and creative skills, especially when they are involved in design-based projects requiring innovative solutions (Guzey & Li, 2023).

Further studies indicate that STEM learning can help students think collaboratively and creatively in addressing real-world problems. STEM-based learning can develop collaborative skills that are essential for creating innovative solutions (Baran, Baran, Karakoyun, & Maskan, 2021). Similarly, other studies report that STEM projects focusing on environmental issues, such as renewable energy, can encourage students to create applicable and relevant solutions for societal needs (Othman, Hassan, & Has, 2022). Additionally, other research finds that STEM-based learning utilizing technology can enhance dimensions of student creativity, such as flexibility and idea elaboration (Wan, So, & Hu, 2021).

Subsequent research reveals that applying the 5E-based STEM model significantly enhances aspects of originality and elaboration in students' creativity (Shahbazloo & Mirzaie, 2023). Moreover, other studies show that the implementation of Design Thinking in STEM learning encourages students to be more creative in developing project-based solutions relevant to the issues they face (Ananda, Rahmawati, & Khairi, 2023).

One innovation within STEM is its integration with Design Thinking (STEM-DT), which offers a systematic learning model through steps like empathize, define, ideate, prototype, and test to produce relevant and applicable creative solutions (Thomason & Hsu, 2024). The STEM-DT learning model is effective in enhancing students' design capabilities through systematic steps, including empathy, problem definition, ideation, prototyping, and testing (Thomason & Hsu, 2024). Research finds that the implementation of STEM-DT not only helps students better understand scientific concepts but also results in high-quality creative products (Simeon, Samsudin, & Yakob, 2022).

Previous research by Sawu, Sukarso, Lestari, & Handayani (2023) explored ecobrick projects as a solution to address environmental pollution, focusing on enhancing students' creative disposition and creative products through a STEM-based learning model. This study focuses on a water filtration project as a solution to environmental issues related to clean water access, which is highly relevant to the needs of communities in flood-prone areas. Regarding the learning model, the STEM learning model used by Sawu, Sukarso, Lestari, & Handayani (2023). involves steps such as Observe (observing the problem), New Idea (generating new ideas), Innovations (creating innovations), Creativity (cultivating creativity), and Society (considering societal benefits). As an innovation, this study integrates STEM with Design Thinking (STEM-DT), which includes the stages of Empathize (understanding the problem from others' perspectives), Define (defining the main problem), Ideate (developing creative ideas), Prototype (creating a solution prototype), and Test/Evaluate (testing and evaluating the solution).

This research aims to explore how the STEM-DT learning model can help students develop a creative disposition while also enhancing the quality of their creative products. With a focus on the water filtration project, this study seeks to broaden insights into the potential of STEM-DT in supporting the development of students' skills in various environmental science topics. The main differences between this research and previous studies lie in the discussed topic and the applied learning model. This research is designed to answer two questions:

1) How does the STEM-DT learning model affect students' creative disposition in the water filtration project? and
2) How does the STEM-DT learning model affect the quality of students' creative products in the water filtration project?

2. METHOD

2.1 Research Design

This study adopted a quantitative method with a quasi-experimental research design. This design was chosen because it can identify the influence of the independent variable (STEM-DT-based learning method) on the dependent variables (students' creative disposition and creative products) under more controlled conditions. By using a quasi-experimental design, this study allows researchers to compare the outcomes between two distinct groups without randomization, providing a deeper understanding of the effectiveness of the applied learning model (Creswell, 2018). The purpose of this study is to determine whether the use of the STEM-DT learning model in the experimental class can enhance students' creative disposition more effectively than the conventional learning model used in the control class. The research design utilized in this study is further detailed in Table 1.

Table 1 Research design

Groups	Pretest	Treatment	Posttest
Experiment	O_1	X	O_2
Control	O_1	-	O_2

Description:
O_1 : Pretest conducted for both the experimental and control classes before treatment;
O_2 : Posttest conducted for both the experimental and control classes after treatment;
X : Treatment using the STEM-DT learning model

2.2 Partcipants

The participants of this study consisted of 52 ninth-grade students from a junior high school. They were divided into two groups: the control group and the experimental group, each consisting of 26 students. The details of the participants are shown in Table 2.

Table 2 Participants

Class	Number of Student	Male	Female
Experiment	26	13	13
Control	26	15	11
Total	52	28	24

This grouping ensured that both the control and experimental groups had balanced characteristics, so any observed differences could more accurately be attributed to the implemented learning model. In this context, students were expected to actively engage in the learning process, whether in the control group using conventional methods or in the experimental group applying the STEM-DT learning model.

2.3 Instruments

The instruments used in this research consisted of two primary tools. First, to measure students' creative disposition, a questionnaire based on the Lucas framework was employed. This questionnaire was designed to evaluate various aspects of creative disposition, including openness to new experiences, risk-taking, and curiosity. The questionnaire contained a series of questions aimed at exploring students' attitudes and behaviors in the context of learning and problem-solving.

Second, to assess the quality of students' creative products, a rubric adapted from the Besemer framework was used. This tool evaluated creative products based on criteria such as originality, innovation, effectiveness, and relevance of the solutions produced by students. The evaluation utilized a clear rubric, ensuring objective and consistent assessments. With these instruments, comprehensive data on students' creative disposition and the quality of their creative products were obtained following the specified treatment. The research instrument used in this study can be further found in Table 3.

Table 3 Research instrument

Dependent Variables	Instrument	Framework
Creative disposition	Likert-scale Questionnaire	(Lucas, 2016)
Creative product	Product Evaluation Sheet	(Besemer, 1998)

Creative Disposition

This instrument is designed to identify changes in students' creative thinking after completing a water filtration project in STEM-DT learning. The creative thinking referred to here is students' habits of applying creativity to solve various challenges. In this study, the concept of creative thinking patterns is adapted from Lucas, Claxton, and Spencer (2013), which includes five main dimensions: curiosity, persistence, imagination, collaboration, and discipline. Each of these main dimensions is broken down into three subdimensions, resulting in a total of 15 subdimensions. Then, each subdimension is translated into two questions in the questionnaire, so the total questionnaire consists of 30 statements. The grid for the creative disposition questionnaire in science learning can be seen in Table 4.

To investigate the quantitative changes in students' creative disposition before and after the practical activities, we designed a questionnaire in a checklist format. This questionnaire contains 30 statements that students must respond to using a Likert scale, consisting of five response categories: Always, Often, Sometimes, Rarely, and Never. Each response category is assigned a different value: 5 for "Always," 4 for "Often," 3 for "Sometimes," 2 for "Rarely," and 1 for "Never." In this way, we can calculate the average creative disposition score for each student based on their responses to the 30 statements provided. Before use, this questionnaire was validated by three experts who are lecturers, and the validation results showed that all the statements were acceptable with only slight revisions in a few sentences.

Creative Product

The creative products produced by students from the implementation of the water filtration project in STEM-DT learning are evaluated using an assessment rubric adapted from Besemer (1998). The evaluation of these creative products includes three main indicators: novelty, resolution, and elaboration and synthesis. The novelty indicator is divided into two sub-indicators, while resolution consists of four sub-indicators, and elaboration and synthesis have three indicators. Thus, there are a total of nine indicators used to assess the students' creative products. The grid for developing the rubric for creative product assessment is shown in Table 5.

Based on this matrix, a Creative Product Assessment Rubric has been developed, which includes 14 assessment items. Each item in this rubric is scored on a scale of 1 to 5, so the maximum score that can be obtained is 45 and the minimum score is 9. Before this rubric is used in implementation, it was validated by three experts who are lecturers, and the validation results showed that all statement items were accepted with only slight revisions to some of the sentences. The assessment process for creative products is conducted by a single evaluator, who is responsible for reviewing, analyzing, and providing feedback on the quality, originality, and effectiveness of the product based on predetermined criteria.

The data obtained were then analyzed using descriptive statistics. The formula for determining the percentage of students' creativity scores is adapted from Riduwan (2015), which involves dividing the students' obtained score by the maximum score of the test, then multiplying by one hundred percent.

$$\%Creativity = \frac{score\ obtained}{maximum\ score} \times 100$$

The results of the percentage data are then categorized based on the criteria in Table 6.

Table 2 Criteria for creativity mastery levels

Total Score Range (%)	Criteria
0 – 20	Not Creative
21 – 40	Less Creative
41 – 60	Moderately Creative
61 – 80	Creative
80 – 100	Very Creative

2.4 Data Analysis

Data analysis is carried out through a series of statistical procedures designed to ensure the accuracy and validity of the research results. First, a normality test is conducted to determine whether the obtained data follows a normal distribution, which is an important assumption in many statistical analyses. The purpose of this normality test is to ensure that further analyses can be performed appropriately. The normality test can be analyzed using the Shapiro-Wilk test. The results of the test indicate that the data is normally distributed if the p-value is greater than 0.05 at a 95% confidence level.

Table 1 Creative disposition questionnaire matrix

Indicator	Sub Indicator	Statement Number	Number of Item
Inquisitive	Feeling curious and asking questions	1,2	6
	Conducting exploration and research	3,4	
	Questioning assumptions or existing conditions	5,6	
Persistent	Not giving up easily when facing difficulties	7,8	6
	Not giving up easily when facing difficulties	9,10	
	Able to accept uncertainty	11,12	
Imaginative	Ability to think with various possibilities	13,14	6
	Ability to connect different things	15,16	
	Using intuition	17,18	
Collaborative	Working with others	19,20	6
	Working with others	21, 22	6
	Sharing results with others	23, 24	
Diciplined	Creating something and improving it	25, 26	
	Using skills in specific techniques	27, 28	
	Critically reflecting	29, 30	

Table 3 Matrix for creative product assessment rubric

Indicator	Sub Indicator	Assessment Item Number
Novelty	Original (new and different from previous products)	1
	Surprise (product attracts attention)	2
Resolution	Valuable (product is considered worthy or valuable by the user)	3
	Logical (product is acceptable and understandable according to rules and disciplines)	4
	Useful (product has clear practical application value or benefit)	5
	Understandable (product is easy to understand)	6
Elaboration and Synthesis	Organic (product has a cohesive meaning)	7
	Elegance (product is expressed in a simple or flexible manner)	8
	Well-crafted (product is made well)	9

Next, a homogeneity test is used to examine the equality of variances between the control and experimental groups. This is important to ensure that the comparison between the two groups is conducted fairly, without bias from significant differences in variance. The decision-making in the homogeneity test is as follows: a) If the significance value (Sig.) > 0.05, the data is considered homogeneous; b) If the significance value (Sig.) < 0.05, the data is considered heterogeneous.

Once these assumptions are met, a t-test will be used to test for differences in the means between the two groups, in order to determine whether the STEM-DT-based learning model has a significant impact on students' creative disposition and creative products. Before conducting the hypothesis test, the statistical hypothesis formulation is as follows:

H_0 : There is no significant difference between the control class with the conventional learning model and the experimental class with the STEM-DT learning model in terms of students' creative disposition and creative products.

H_a : There is a significant difference between the control class with the conventional learning model and the experimental class with the STEM-DT learning model in terms of students' creative disposition and creative products.

The decision rule is to accept H0 if $p > 0.05$ and reject H0 if $p < 0.05$ with a 95% confidence level.

To measure the effect size of the treatment, Cohen's d test is applied. This test will provide information on how much impact the applied method has on the variables being studied. Additionally, the N-Gain test is conducted to evaluate the improvement in students' creative disposition and creative products after the treatment, which provides an indication of the effectiveness of the intervention. The N-Gain formula based on Hake (1998) is as follows:

$$Normalized\ Gain = \frac{posttest\ score\ - pretest\ score}{maximum\ score\ - pretest\ score}$$

For categorization, we can use the interpretation of the normalized Gain index (g) according to Hake (1998), as modified, which can be seen in the following Table 7.

Table 4 Interpretation of n-gain index

N-Gain Score (g)	Interpretation
$0 < g < 0.30$	Low
$0.30 < g < 0.70$	Moderate
$0.70 < g < 1.00$	High

2.5 Research Procedure

In the experimental group, the learning uses the STEM-DT learning model, which consists of five stages: empathize, define, ideate, prototype, and test/evaluate. A more detailed explanation of the implementation of these steps can be seen in Table 8.

On the other hand, in the control group, the learning process follows the conventional teaching model that the teacher has used previously. This learning process begins with the stage of determining the problem, where students observe the surrounding environment to identify clean water-related issues. They discuss in groups and draw conclusions about the main problems they discovered. Next, in the solution design stage, students discuss how to filter dirty water, brainstorm ideas, select simple materials and tools, and determine the best solution based on effectiveness and ease of implementation. In the final stage, developing the product, students design posters that include the identification of clean water problems, proposed solutions, step-by-step processes, and supporting images. This poster is expected to provide clear and educational information to the public on how to address clean water issues.

Table 5 Research Procedure for the Experimental Class

STEM-DT Syntax	Activity
1. Empathize	Observing the Surrounding Environment Conduct in-depth interviews (IDI) and draw conclusions from the interview results related to clean water issues.
2. Define	Formulating the Main Problem Based on the interview results, analyze the clean water issues faced by the informants, identify needs, and formulate the main problem and solution ideas.
3. Ideate	Selecting the Water Filtration Device Design Conduct an open discussion (brainstorming) to propose filtration device design ideas, evaluate ideas, and select the best design based on criteria such as effectiveness, ease of construction, and material availability.
4. Prototype	Water Filtration Project Create a design for the water filtration product, illustrate the prototype design, prepare tools and materials, and create a plan for the project construction.
5. Test	Prototype Testing Test the created prototype, note the strengths and weaknesses of the product, and present the results to other groups to receive feedback and suggestions for improvement.
6. Evaluate	Redesign Prototype Improve the prototype based on the feedback received, evaluate the improvements, and note the new strengths and any remaining challenges with the prototype.

3. RESULT AND DISCUSSION

3.1 Result of Creative Disposition

This study measures students' creative disposition based on five main dimensions: curiosity (inquisitive), perseverance (persistent), imagination (imaginative), risk-taking, and collaboration. Descriptive analysis results show a difference in the average creative disposition scores between the experimental and control classes. The following are the descriptive statistics for students' creative disposition in both classes, as shown in Table 9.

Table 6 Descriptive statistics

	N	Min.	Max.	Mean	Std. Deviation
Control Pretest	26	71	113	91.35	12.432
Control Posttest	26	66	137	95.27	15.848
Experimental Pretest	26	77	137	98.46	15.761
Experimental Posttest	26	82	149	105.08	17.586

This table shows the pretest and posttest results for the control and experimental classes. In the control class, the average pretest score was recorded at 91.35, with a minimum score of 71 and a maximum score of 113. The variation in scores in the control class is indicated by the standard deviation of 12.432, which suggests that most students had scores relatively close to the average. After the learning process with the conventional method, the average posttest score increased to 95.27, while the minimum score decreased to 66 and the maximum score increased to 137. The standard deviation of 15.848 in the posttest indicates an increase in score variation, meaning that students' responses to conventional learning were quite diverse.

In the experimental class, the average pretest score was higher compared to the control class, at 98.46, with a minimum score of 77 and a maximum score of 137. The standard deviation of 15.761 indicates that the pretest scores in this class were more spread out, with some students showing scores far from the average. After the implementation of STEM-DT-based learning, the average posttest score of students significantly increased to 105.08, higher than in the control class. The minimum score in the experimental class increased to 82, while the maximum score reached 149, which was the highest in all groups. The standard deviation of 17.586 in the experimental class posttest indicates that the STEM-DT learning model had a more varied impact on students, with some experiencing significant score increases.

The comparison between the control and experimental classes shows that the STEM-DT learning model has a greater impact on improving student learning outcomes compared to conventional teaching. The higher average posttest scores in the experimental class indicate the effectiveness of the STEM-DT learning model in enhancing student understanding. Although these descriptive statistics provide an initial overview of the score differences between the two classes, these results are not sufficient to conclude the statistical significance of the differences. Therefore, to ensure the data meet the requirements for parametric statistical testing, normality and homogeneity tests were performed. The results of the normality test can be seen in Table 10.

Table 8 Normality test

Class	Shapiro-Wilk		
	Statistic	df	Sig.
Control Pretest	.957	26	.343
Control Posttest	.956	26	.325
Experiment Pretest	.950	26	.233
Experiment Posttest	.933	26	.094

The results of the normality test using Shapiro-Wilk show that the pretest and posttest data in both classes are normally distributed. In the control class, the significance value for the pretest is 0.343, and for the posttest is 0.325, both greater than the significance threshold of 0.05. Similarly, in the experimental class, the significance values for the pretest and posttest are 0.233 and 0.094, respectively, both greater than 0.05. These results indicate that the data for all groups meet the normality assumption, so parametric statistical analysis, such as a t-test, can proceed. Furthermore, a homogeneity test was performed using Levene's Test to check the equality of variances between the groups. The results of the homogeneity test can be seen in Table 11.

Table 7 Homogeneity test

	Levene Statistic	df_1	df_2	Sig.
Based on Mean	.647	3	100	.587
Based on Median	.567	3	100	.638
Based on Median and with adjusted df	.567	3	92.426	.638
Based on trimmed mean	.627	3	100	.599

Based on the mean, the significance value is 0.587, while based on the median, the significance value is 0.638, and for the trimmed mean, it is 0.599, all greater than 0.05. These results show that the variance of data from both classes is homogeneous, thus satisfying the homogeneity assumption. Since both tests indicate that the data are normally distributed and have homogeneous variance, the analysis proceeds with the t-test. The t-test was performed to test the difference in the average posttest scores between the control and experimental classes, considering the assumption of equal variances. The results of the t-test can be seen in Table 12.

The t-test results show a t-value of -2.112 with 50 degrees of freedom (df) under the assumption of equal variances. The significance value (2-tailed) is 0.040, which is smaller than the significance level of 0.05. This indicates a significant difference in the average scores between the control and experimental groups. The mean difference between the control and experimental classes is -9.808, with a standard error of 4.643, suggesting that the STEM-DT learning model has a significant impact on the creative disposition of students compared to conventional teaching methods.

After performing the t-test, which showed a significant mean difference between the control and experimental groups, an effect size calculation was carried out using Cohen's d to measure the impact of the STEM-DT learning model on student learning outcomes. The calculation resulted in a Cohen's d value of 0.586037, which falls within the "medium" category (Cohen, 1988). This Cohen's d value indicates that although there is a significant difference between the two groups, the impact of the STEM-DT learning model on improving student learning outcomes is moderate. In other words, while the STEM-DT learning model is effective in improving student learning outcomes, its effect is not as large as might be found in some more intensive interventions. The N-Gain scores for each class can be seen in Table 13.

Additionally, based on the descriptive analysis in the N-Gain table, the average N-Gain score for the control class is 0.0508 with a standard deviation of 0.24888, while the experimental class has an average of 0.1213 with a standard deviation of 0.31052. The higher average in the experimental class suggests that the STEM-DT learning model is more effective in improving student learning outcomes compared to the conventional method. The maximum N-Gain value in the experimental class (0.95) is also higher than in the control class (0.79), indicating that the STEM-DT learning model allows some students to achieve near-optimal learning outcomes. However, the minimum values in both groups show that some students experienced a decline in learning outcomes, with a greater decrease in the control class (-0.46) compared to the experimental class (-0.26).

Table 9 T-test

	t-test for Equality of Means				
	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Equal variances assumed	-2.112	50	.040	-9.808	4.643
Equal variances not assumed	-2.112	49.468	.040	-9.808	4.643

Table 10 N-gain scores

	N	Minimum	Maximum	Mean	Std. Deviation
N-Gain Score Control	26	-0.46	0.79	0.0508	0.24888
N-Gain Score Experiment	26	-0.26	0.95	0.1213	0.31052

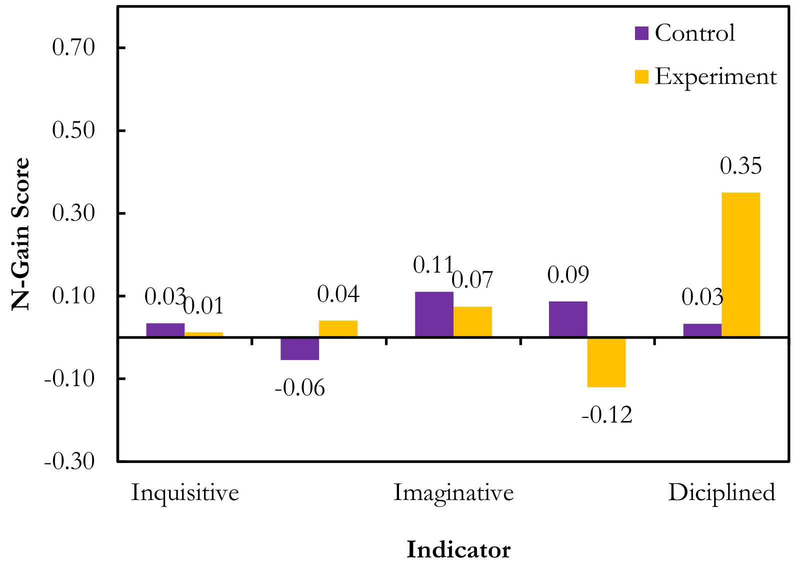

Figure 1 N-Gain for each indicator

The graph in Figure 1 presents a comparison of N-Gain scores between the experimental and control groups for each indicator, which includes inquisitive, persistent, imaginative, collaborative, and disciplined.

Based on Figure 1 above, it is observed that the learning implemented in the control and experimental groups shows differences in the improvement of students' creative disposition dimensions, although in general, the results are still categorized as low. In the Inquisitive indicator, the control group obtained an N-Gain score of 0.03, while the experimental group scored 0.01, both of which fall into the low category. This indicates that the learning in both the control and experimental groups was not able to significantly enhance students' curiosity during the learning process.

In the Persistent indicator, the control group showed an N-Gain score of -0.06, which not only falls into the low category but also indicates a decline in students' perseverance. On the other hand, the experimental group obtained a score of 0.04, which, although still low, reflects a slight improvement compared to the control group. This difference may suggest that the learning learning model in the experimental group has the potential to enhance students' perseverance, although it is not yet optimal.

For the Imaginative indicator, the control group obtained an N-Gain score of 0.11, while the experimental group scored 0.07, both falling in the low category. Although the control group had a slightly higher score, this difference is not significant and shows that neither learning method has had a meaningful impact on developing students' imagination.

In the Collaborative indicator, the control group recorded an N-Gain score of 0.09, while the experimental group experienced a decline with a score of -0.12, both in the low category. The decrease in the experimental group's score suggests that the learning model implemented may be less effective in building students' ability to collaborate in teams.

Next, different results are seen in the Disciplined indicator. The control group showed an N-Gain score of 0.03, which is categorized as low, while the experimental group recorded a score of 0.35, which is in the moderate category. This difference indicates that the learning model in the experimental group was significantly more successful in improving students' discipline compared to the control group. This suggests that the application of the STEM-DT learning syntax in the experimental group has advantages in forming students' discipline, although it still requires optimization for other indicators.

Overall, the data indicates that although there are small differences between the control and experimental groups, most of the creative disposition dimensions of the students remain in the low category. These results emphasize the importance of improving the learning design, particularly in aspects related to collaboration, curiosity, and perseverance, to achieve more optimal outcomes.

3.2 Impact of STEM-DT on Students' Creative Disposition

The steps in the STEM-DT learning syntax provide a clear picture of how this learning model supports the development of students' creative disposition. This creative disposition includes five main dimensions: curiosity, perseverance, imagination, risk-taking, and collaboration. Previous research shows that STEM-DT learning model, which integrates STEM with Design Thinking, can enhance students' creative skills, especially in problem-solving and innovation contexts (Li et al., 2019; Simeon, Samsudin, & Yakob., 2022). his learning model allows students to think more openly and creatively, as well as to view real-world problems from a broader perspective (Topsakal, Yalçin, & Çakir, 2022).

In contrast, in conventional learning, students are often engaged in activities that are more structured and limited. Activities like observing environmental issues or group discussions tend to focus on solving well-known problems without providing much opportunity for further exploration (Ha, Chung, Hanh, Van, & Hai, 2023). Students are asked to answer questions such as "What causes water pollution?" or "How can it be solved?" without being given space to think more critically or explore new ideas. This is why the Empathize stage in STEM-DT becomes crucial, as students are encouraged to delve deeper into real-world issues, such as water pollution, through interviews or direct observations (Ning, Salleh, & Cai, 2023; Thomason & Hsu, 2024). This process not only enhances their curiosity but also provides an opportunity to connect previously separate information, thereby promoting critical thinking and increasing students' intrinsic motivation to learn and explore further (Sawu, Sukarso, Lestari, & Handayani, 2023; Thomason & Hsu, 2024; Wingard, Kijima, Yang-Yoshihara, & Sun,, 2022).

The Define stage in the STEM-DT learning model plays a key role in supporting the development of indicators of students' creative disposition, particularly in terms of curiosity, perseverance, and risk-taking. Through the process of analyzing and formulating the problems they encountered during the Empathize stage, students are encouraged to dig deeper and question existing assumptions, which enhances their curiosity about real-world issues. The analysis results from students' interviews with sources regarding the needs related to access to clean water revealed that the main need is a water filtration system to obtain cleaner and safer water, due to the increasing difficulty in obtaining natural clean water sources. Filtration is needed to protect the health of families from various diseases caused by harmful contamination. The greatest need identified is for purposes such as drinking and cooking. The results of the needs identification conducted by the students can be seen in Figure 2.

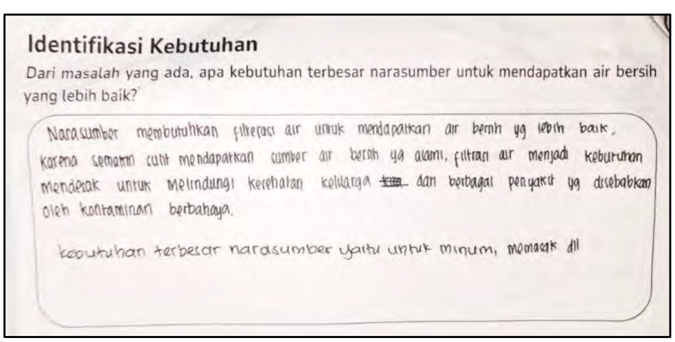

Figure 2 Needs analysis based on issues

This process also trains perseverance, as students must filter relevant information to formulate the problem accurately, even though they may go through several stages of re-formulation (Simeon, Samsudin, & Yakob, 2022; Thi Hong, 2024). Additionally, this stage hones the courage to take risks, as students are required to boldly formulate problems in new or different ways that they may not have considered before. Research by Li., et al (2019) shows that in this process, students not only learn to structure problems but also face uncertainty and try more creative models to problem-solving. Thus, the Define stage not only helps students better understand the problem but also develops their creative disposition to think more openly, deeply, and courageously confront challenges.

Next, in the Ideation stage, the STEM-DT learning model provides students with more room to develop their imagination. Students are encouraged to brainstorm in groups and generate various ideas without fear of making mistakes. Several filtration design ideas were proposed by the students, including the first design utilizing a cut and inverted plastic bottle, filled with filtration layers such as sand, charcoal, and cotton. The next design uses a cut plastic bottle attached to a faucet, also equipped with similar filtration materials. The final design uses an inverted jar with supports, layered with filters such as cloth or cotton. All of these ideas demonstrate innovation in utilizing simple materials to create functional water filtration devices. A more complete result of the brainstorming can be seen in Figure 3.

Figure 3 Brainstorming on filter device design

This learning model is very different from conventional learning, which tends to direct students toward one solution considered "correct." Here, students are given the freedom to explore various alternatives and are encouraged to propose ideas they may not have considered before. This trains them to be more willing to take risks in finding solutions and creates an environment where creativity can develop more freely (Diep et al., 2023; W. Li & Li, 2022; Simeon, Samsudin, & Yakob, 2022). In this context, Vygotsky's Zone of Proximal Development (ZPD) theory is highly relevant, as the teacher's support enables students to go beyond their initial capabilities and try more creative and daring ideas (Margolis, 2020). With proper guidance, students feel safer in presenting innovative ideas without the fear of failure.

Then, in the Prototype and Test/Evaluate stages, students are given the opportunity to apply their ideas in the form of prototypes that can be tested. This is a step that involves perseverance, where students must face failures and technical challenges but remain motivated to find better solutions. Some examples of the prototypes created by students can be seen in Figure 4.

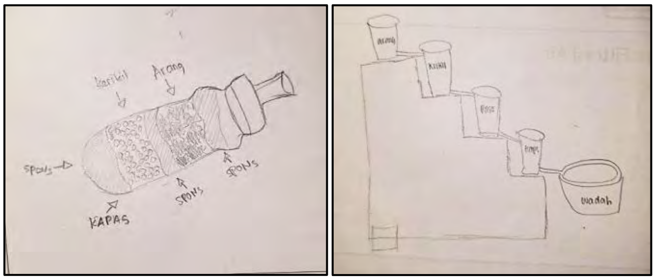

Figure 4 Prototype of water filtration

Unlike conventional learning, which often focuses solely on presenting ideas without real implementation, STEM-DT provides hands-on experience in designing, testing, and refining solutions. Research shows that students engaged in STEM-DT-based learning exhibit higher resilience when faced with difficulties and are less likely to give up when encountering obstacles (Zhao, He, Liu, Tai, & Hong, 2021). This learning model also fosters a growth mindset in students, where they learn to see challenges as opportunities for growth, not as barriers (Zhang, 2022).

The final stage, the Redesign phase, emphasizes the importance of collaboration. After receiving feedback, students work together to refine their solutions. The group discussions during this phase provide an opportunity for students to listen to others' perspectives, offer constructive criticism, and collaborate in improving their designs. This contrasts with conventional learning, where group discussions are often limited to idea exchanges without further iteration. In STEM-DT, collaboration not only results in better solutions but also trains students to value diverse ideas in achieving a shared goal. Research supports that collaboration in STEM-DT-based learning allows students to learn how to work in teams and generate more innovative ideas (Li et al., 2019; Simeon, Samsudin, & Yakob, 2022).

Although STEM-DT has proven to be more effective in enhancing students' creative disposition compared to conventional learning, the analysis results indicate that this improvement remains in the moderate category. The average post-test score in the experimental class was higher (105.08) than in the control class (95.27), but the N-Gain value, which only reached 0.1213, suggests that its impact has not yet been fully optimized. One factor influencing this is the higher pre-test score in the experimental class (98.46) compared to the control class (91.35), limiting the room for further improvement. Additionally, students still require time to adapt to the STEM-DT learning model, which demands more independent exploration and creative thinking.

The impact of STEM-DT learning on each aspect of creative disposition also varies. The discipline indicator showed the most significant improvement, with an N-Gain of 0.35, indicating that this model effectively fosters students' self-regulation in completing tasks and following iterative design thinking processes. However, the collaboration indicator actually declined (-0.12), possibly due to ineffective facilitation during the Ideation and Redesign stages, preventing strong interactions among students. Other indicators, such as curiosity (0.01), perseverance (0.04), and imagination (0.07), remained low, suggesting that while STEM-DT provides a broader space for exploration, students still require more guidance and experience to develop these aspects optimally.

Overall, the STEM-DT learning model has been proven to be beneficial in enhancing students' creative disposition, particularly in the aspect of discipline. However, its moderate impact highlights the need for more targeted strategies to strengthen collaboration, curiosity, and perseverance. Optimizing instructional methods, such as providing stronger scaffolding during exploration and problem-solving stages and enhancing interaction in group work, can be crucial steps in ensuring that STEM-DT maximally fosters students' creativity across various aspects.

3.3 Result of Creative Products

As part of the analysis of the research results, an evaluation was conducted to assess the impact of the STEM-DT learning model on creative products. Each group created a creative product in the form of a water filtration device according to the creative design that had been developed. The descriptive statistical results of the creative product evaluation can be seen in Table 14.

Table 11 Descriptive statistics of students' creative products

	N	Min.	Max.	Mean	Std. Deviation
Control Class	6	16	27	22.00	3.847
Experimental Class	6	29	43	37.83	5.269

The descriptive statistics in Table 14 show a marked difference in the creative products of students between the six groups in the control class and the experimental class. In the control class, the minimum score of students' creative products was 16, while the maximum score reached 27, with an average of 22.00 and a standard deviation of 3.847. This value indicates a relatively low but homogeneous level of creativity among the groups. In contrast, in the experimental class, the minimum score of students' creative products was much higher, at 29, with the maximum score reaching 43. The average score in the experimental class was 37.83, with a standard deviation of 5.269, reflecting a higher and more varied level of creativity compared to the control class. These results indicate that the learning model applied in the experimental class was

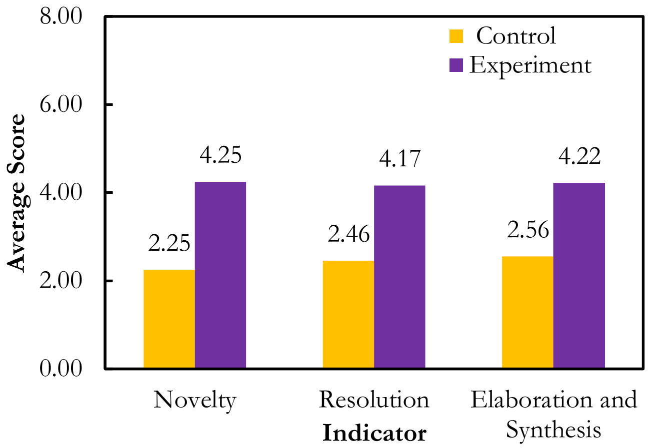

Figure 5 Comparison of the average scores of both classes on each indicator

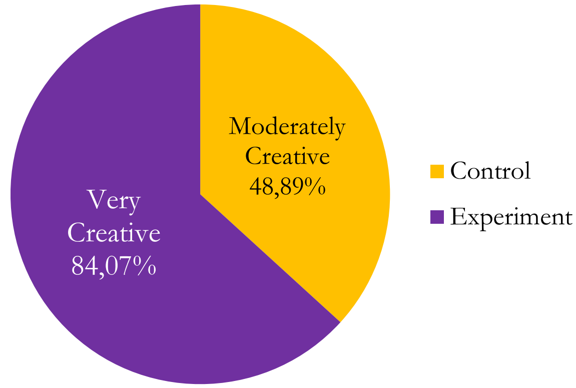

Figure 6 Category of creative product score for the second class

more effective in fostering students' creativity compared to the method used in the control class.

Figure 5, which will show a comparison of creative product results per indicator between the two groups that were applied with different learning models, namely the experimental class using the STEM-DT learning model and the control class following the conventional learning model.

Based on Figure 5, which illustrates the difference in the average creativity scores of students between the control class and the experimental class across three main indicators: novelty, resolution, and elaboration and synthesis. In the novelty indicator, which reflects the students' ability to generate new ideas, the control class only achieved an average score of 2.25, while the experimental class showed a much higher score of 4.25. This difference indicates that students in the experimental class were more capable of producing innovative ideas. The resolution indicator, which measures students' ability to provide effective solutions, also shows similar results. The control class received an average score of 2.46, while the experimental class excelled with a score of 4.17. This indicates that students in the experimental class were more skilled at solving problems compared to those in the control class. Lastly, on the elaboration and synthesis indicator, which assesses how well students can develop and integrate their ideas, the control class only achieved an average score of 2.56. In contrast, the experimental class again excelled with an average score of 4.22, indicating that the learning model applied in the experimental class was more successful in training students to think more deeply and systematically. Overall, these results show that learning in the experimental class was able to significantly enhance students' creativity compared to the control class. Furthermore, the categorization results of creative products can be seen in Figure 6.

Based on Figure 6, it shows that for the control class, the average score of 48.89% falls into the "Fairly Creative" category. This indicates that the students in this class have a moderate level of creativity but have not yet fully maximized it. They can think creatively, but they are not yet able to develop more innovative or original ideas. In contrast, in the experimental class, the higher average score of 84.07% shows that the students in this class are highly creative. They are able to generate new ideas and more innovative learning models to learning. This reflects the effectiveness of the teaching learning model applied, which is more interactive and supports the development of students' creativity. With this score, they fall into the "Very Creative" category, which indicates their ability to think outside the box and generate more original solutions. This difference illustrates that the STEM-DT learning model implemented in the experimental class has a significant positive impact on the development of students' creativity. The more dynamic and in-depth learning model gives students the opportunity to explore their ideas more freely and innovatively, while in the control class with the conventional learning model, students' creativity is still in a more developing stage.

3.4 Impact of STEM-DT on Students' Creative Products

The STEM-DT learning model has been proven to have a significant impact on enhancing students' creative products, as evidenced by the differences in creative product scores between the experimental and control classes. Data in Table 14 shows that the average creative product score in the experimental class reached 37.83, significantly higher than the control class, which only scored 22.00. Additionally, the score range in the experimental class was broader (29–43) compared to the control class (16–27), indicating that this learning model not only enhances overall creativity but also allows for a greater diversity of ideas. This means that STEM-DT not only fosters creativity but also provides students with the opportunity to explore more innovative solutions based on their understanding and experiences.

The STEM-DT provides a comprehensive learning model to developing students' creativity, reflected through three main indicators: Novelty, Resolution, and Elaboration and Synthesis. In the Novelty indicator, this learning creates space for students to generate original and surprising ideas. This aligns with the quantitative results in Figure 5, which show that the Novelty score in the experimental class reached 4.25, significantly higher than the control class, which scored only 2.25. This difference reflects how the Ideation stage in STEM-DT enables students to brainstorm freely without fear of making mistakes. A supportive environment allows students to explore new ideas with confidence Chien, Liu, Chan, & Chang, 2023; Csikszentmihalyi, 2012). Teachers play an important role as facilitators, ensuring that each student feels their contributions are valued. For example, in the water filtration project, students can design innovative solutions using standard sensors to monitor water quality in real-time. The activity of using standard sensors to monitor water quality is illustrated in Figure 7.

Figure 1 Monitoring water quality with standard sensors

This solution not only showcases students' creativity but also relevance to community needs (Arifin & Mahmud, 2021; Suciani & Prima, 2020). Previous research supports that this learning model significantly enhances students' ability to generate fresh and innovative ideas (Puchongprawet & Chantraukrit, 2022; Sawu, Sukarso, Lestari, & Handayani, 2023). In contrast, traditional learning models like poster creation offer limited space for idea exploration. Students' creativity in making posters is generally confined to visual and conceptual aspects, without real-world experience in solving complex problems. This makes the STEM-DT learning model superior in opening up opportunities for innovation compared to traditional methods, which tend to limit students' creative scope.

After generating ideas, the learning process continues with a focus on the Resolution indicator, which measures the extent to which students' products are valuable, logical, useful, and easy to understand. STEM-DT has a significant impact in this regard. Quantitative results in Figure 2 show that the experimental class achieved a score of 4.17 in this aspect, which is higher than the control class, which only scored 2.46. This improvement reflects the effectiveness of the Define stage, where students analyze interview results or observations to formulate the main problem more specifically. This process helps students understand issues more deeply, such as the need for clean water access in flood-prone areas. This understanding is then translated into solution designs that are not only effective but also have a real impact (Ning, Salleh, & Cai, 2023). Next, in the Test/Evaluate stage, students test their prototypes to ensure the tools they create meet the defined needs. This stage also provides space for reflection, where students recognize the strengths and weaknesses of their designs. This process strengthens students' critical thinking abilities, helping them produce logical and applicable solutions (Puchongprawet & Chantraukrit, 2022). A study shows that the STEM-DT learning model helps students create products that are not only logical but also socially and practically relevant (Li et al., 2019; Thi Hong, 2024). On the other hand, the poster-making learning models only produces a visual representation of the water filtration concept, without any proof or testing of the proposed solution's effectiveness. The end result is theoretical and does not provide direct experience in solving real-world problems in the community.

The final indicator, Elaboration and Synthesis, demonstrates students' ability to integrate various elements into a sleek and structured product design. In Figure 5, the score for this indicator in the experimental class reached 4.22, higher than the control class, which only scored 2.56. This indicates that students who participated in STEM-DT learning were better able to integrate various aspects into their designs compared to those who followed conventional methods. In the Prototype stage, students learn to combine filtration materials with standard sensor technology to create functional and aesthetically pleasing products. They are also encouraged to pay attention to technical details and design so that the products they create not only work well but are visually appealing (Besemer, 1998; Chien, Liu, Chan, & Chang, 2023). This process is further deepened in the Redesign stage, where students receive feedback from teachers and peers to refine their designs. This iteration not only improves the product's quality but also helps students see the connections between various elements in their design. This aligns with research emphasizing that the balance between function and aesthetics is key to good creative products (Horn & Salvendy, 2006). Examples of redesign results from students can be seen in Table 15.

On the other hand, elaboration in poster creation is limited to organizing information visually. There are no real technical challenges to solve, thus providing minimal opportunities to develop technical skills or integrative thinking.

The entire process demonstrates how STEM-DT learning supports the holistic development of students' intelligence, in line with the theory of Multiple Intelligences (Kornhaber, 2019). By integrating various intelligences,

Table 12 Students' product results

Initial Product	Final Product
	

such as logic, creativity, and empathy, this learning not only focuses on the outcome but also on the process that involves collaboration, reflection, and the courage to take risks. With this learning model, students not only produce products that meet the Novelty, Resolution, and Elaboration and Synthesis indicators, but are also prepared to face real-world challenges with innovative, relevant, and meaningful solutions. The STEM-DT learning model proves itself as an effective learning model in comprehensively fostering students' creativity.

4. CONCLUSION

Based on the research findings, there is a significant difference in creative disposition between the experimental group and the control group through the implementation of the water filtration project. The T-test results show an Asymp.Sig. (2-tailed) value of 0.040, which is less than 0.05, supporting the presence of a statistically significant difference. This is reinforced by descriptive statistics, which show that the average posttest score of the experimental group reached 105.08, higher than the control group's average of 95.27. Additionally, the N-Gain calculation shows that the experimental class's average score (0.1213) is higher than the control class's (0.0508), indicating that the STEM-DT learning model is more effective in improving student learning outcomes.

The categorization of creative products also supports this finding. The experimental group achieved an average creativity score of 84.07%, which falls into the "Very Creative" category, compared to the control group, which only reached 48.89%, categorized as "Quite Creative." This difference reflects that the STEM-DT learning model can encourage students to produce more innovative and creative products, while also enhancing critical and creative thinking competencies.

Furthermore, for future research, further exploration is needed on optimizing the STEM-DT learning model at various educational levels and in other subjects. In addition, a more in-depth analysis of factors influencing the effectiveness of STEM-DT-based learning, such as student engagement, collaboration skills, and the long-term impact on creative disposition, is an important research agenda to ensure its continued benefits in education.

Overall, the application of STEM-DT in learning can enrich students' learning experiences, provide opportunities for more creative and innovative thinking, and encourage students to generate solutions that have a direct impact on societal issues. Therefore, the STEM-DT learning model is highly recommended to be implemented in learning at various educational levels, as an effort to prepare students to face the increasingly complex and uncertain challenges of the future

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