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Investigating Students' Creativity through STEM-Engineering Design Process in Element, Compound, and Mixture Topic

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ABSTRACT

The STEM-Engineering Design Process is one of the learning models that encourage students to do engineering activities to solve real-life problems. This study aims to investigate the effect of the STEM-Engineering Design Process on students' creativity in element compound, and mixture topics. A quasi-experimental design is used in this study. The implementation of the STEM-engineering design process was conducted in the experiment class, while the control class carried out conventional learning. Both classes are making water filtration tools. Purposive technique sampling was carried out to choose the sample with a certain category of 9th-grade students in one of the private schools in Bandung, West Java, Indonesia. Students ranged in age from 14-15 years old and were divided into experiment and control classes. Each class has 19 students. This research uses a creativity questionnaire Likert scale to collect the data. The result of this study showed there is no significant difference in students' creativity between experiment and control class. The N-Gain scores in the experiment and control class are 0.06 and 0.03 which are described as low. Even though the gain is low, there is still a difference between the experiment and control class in the favour of experiment class. The STEM-engineering design process has a positive impact on creativity in learning element compounds and mixtures.

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1. INTRODUCTION

In 2015, The World Economic Forum reported 16 skills needed for humans to face 21st-century challenges, one of which is creativity (Altan & Tan, 2020; Miller & Dumford, 2016). Entering the 21st century, humans are required to have high quality in the era of industrialization and globalization (Winarni *et al*., 2022). Education is an important aspect of preparing high-quality human resources. As part of education, science education also has an important role in producing human resource which has the qualities needed by humans in the 21st century, especially in the field of science and technology. By developing creativity in the process of learning, students can have meaningful learning in science education. A STEM learning approach is a learning approach that can upskill and prepare high-quality human resources (HR) according to the skill requirements of the 21st century (Jang, 2016). STEM brings together four elements by focusing on solving real problems in everyday life (Erduran, 2020; Winarni *et al*., 2022). Integrated STEM education is learning that uses science, technology, engineering, and mathematics in real-world contexts to develop STEM competencies that enable learners to compete in the new economic era (Sulistiyowati *et al*., 2018). One approach to growing more integrated STEM learning is through engineering experiences housed in real-world contexts that leverage concepts from mathematics, science, and technology (English, 2015). An important aspect of engineering is the development of the design process (English *et al*., 2017). In 2013, Next Generation Science Standard released a statement regarding the need for integration between science and engineering. Science teachers are expected to deliver science concepts using scientific and engineering practices (Guzey *et al*., 2016). Based on Winarno *et al*., (2020) it is beneficial to implement an engineering design process in science education including cognitive benefits, procedural (skills) benefits, attitudinal benefits, and a combination of the three benefits. Nevertheless, based on Nordin (2022), in 2019-2021 there was a significant decline in science engineering research due to pandemic conditions.

The STEM Engineering Design Process model is recognized as a general model of the creative process that can be applied to STEM courses (see https://digitalcommons.usu.edu/ncete_publications/166; Siew, 2017). Creativity according to Hanif *et al*. (2019) is the ability to create an original product or solution to an open-ended task. EDP is one of the STEM branches that encourages students to learn from failure with the engineering step to find a solution to a problem. Nevertheless, one of the fundamental concepts of real-world engineering is that there is no one right solution to a problem. Instead, it is a process and mindset for engineers to develop their creative solutions to problems (Veety *et al*., 2018). In this respect, the engineering design process can develop students' creativity. This concept of the engineering design process is in line with Berland *et al*., (2014) quoted from the National Academy of Engineers & National Research Council (2009); and the National Research Council (2012) that the problem will have multiple possible solutions and it is the engineers that must generate multiple solutions until develop a system to choose the best solution. According to this response, creativity has an important role in the engineering process not only in making creative products but also in developing various solutions to a problem.

Based on Kozbelt *et al*. (2010), there is an alliterative framework that is frequently used in the study of creativity named "Four P's". They are Person, Process, Product, and Press/Place. The "person" component relates to research into the psychological traits and behavioral features associated with creative people, while the "process" component refers to the numerous cognitive processes involved in creative performance. The "product" component focuses on evaluating creative products and attempting to find more precise features that result in this creative classification. Finally, the "press" component focuses on how an individual's surroundings can affect creative functioning. Those components of creativity can’t be separated. However, most of the creative processes are measured based on actual creative outputs which is the basic feature of most divergent thinking tests (Miller, 2014). While the creative process measurement is lacking in availability. Therefore, Miller (2014) in her study developed an instrument that can be used to measure the creative process consisting of six sub-scales such as idea manipulation, imagery/sensory, flow, metaphorical/analogical thinking, idea generation, and incubation. Creativity is indeed an important factor in all engineering design processes (Zheng *et al*., 2018).

The most famous step of the engineering design process model among science and engineering educators is the Massachusetts Department of Education Engineering Design Process Model. Even in one of the studies from Veety *et al*. (2018), the steps of the engineering design process that most teachers choose are similar to the Massachusetts Department of Education Engineering Design Process Model which then called into the easier abbreviated name as DEAL (determine the problem, evaluate possible solutions, apply the best solution, look back and reflect). From this model, another model also developed such as the DIGIER model from Han and Shim (2019) with the steps are defining the problem, ingathering information, generating the solution, implementing the best solution, evaluating the solution, and reflecting. Other models are presented by (Hammack *et al*., 2015; Berland *et al*., 2014; Alemdar *et al*., 2018; English *et al*., 2017; Nurtanto *et al*., 2020; Park *et al*., 2018; Shahali *et al*., 2017; Altan *et al*., 2021; Zhou *et al*., 2017; Siew, 2017; Baydere & Bodur, 2022). However, the main step in the engineering design process which all the various models from those researchers are defining the problem well, making various solutions, choosing the best solution, implementing the solution by making a product, and communicating the result to evaluate the product.

The previous research on creativity in STEM education has already been done by many researchers (Altan & Tan, 2020) to examine the concepts of creativity in Design-Based Learning and to determine the students’ perceptions of this step. Investigate the effect of STEM applications designed for the atomic system and periodic system unit on the scientific creativity of 9th-grade students (Eroglu & Bektas, 2022). Based on Siew *et al*. (2016) STEM-EDP can foster students’ creativity, problem-solving skills, and thinking skills in rural secondary. Huang *et al*. (2020) analyzed the effects of creative thinking, psychomotor skills, and creative self-efficacy (CSE) on engineering design creativity. Avsec and Savec (2019) examine the role of interdisciplinary augmentation can enhancing students’ creativity synergy with critical thinking. The research conducted a critical case study of engineering pedagogy showed that one of the aspects of creativity, convergent thinking, was well represented in engineering courses (Daly *et al*., 2014). While in Miller *et al*. (2021), compare and contrast social science and engineering approaches using design ratings of nearly 1000 engineering design ideas. From all the previous studies already stated, only a study from Conradty and Bogner (2018) quantifies individual creativity using the same instrument as the present research on creativity, which is Cognitive Processes Associated with Creativity (CPAC) by Miller (2014).

The previous study only used 10 items of questionnaire in the form of a Likert scale with ranges from 1 up to 4 and did not implement STEM engineering design process in learning element, compound, and mixture topics. However, this research investigates the effect of the engineering design process on students’ creativity using a CPAC questionnaire of 28 items with a Likert scale ranging from 1 up to 5 in learning element, compound, and mixture topics.

Therefore, this study aims to investigate the effect of the STEM-Engineering Design Process on students' creativity in element compound, and mixture topics.

2. METHODS

2.1. Research Design

The method of this research is quantitative. A quasi-experimental design was chosen to know the influence of treatment in this research. In this design, there are two groups namely experimental and control groups. Both groups will take pre-test and post-test, but only the experimental group that conduct a treatment. The experimental group uses the STEM-engineering design process while the control group uses conventional learning with the same project in both classes. According to Creswell, the basic intent of an experimental design is to test the impact of a treatment (or an intervention) on an outcome, controlling for all other factors that might influence that outcome. The design of this research is a Pretest-Posttest Control Group Design as shown in **Table 1**.

Table 1. Pretest-posttest control group design.

Experiment Class	O_1	X	O_2
Control Class	O_1	-	O_2

As depicted in **Table 1**, O_1 is defined as a Pre-test and O_2 as a Post-test. X indicated the experiment class implemented a STEM-engineering design process while the control class used conventional learning with a project to fairly judge between the experiment and the control class.

2.2. Participant

The research's subject is 9th-grade students from one of the private schools that use an Independent Curriculum in Bandung, West Java, Indonesia. The student's ages range from 14 to 15 years old and never learned about element, compound, and mixture topics. The sampling method used in this study is purposive technique sampling because this research uses quasi-experiment which needs two classes with the same average score in science. The details of the sample based on gender in both classes are shown in **Table 2**.

Table 2. Detail of research sample based on gender.

Gender	Frequency	Percentage
	Experiment Class	
Male	11	58%
Female	8	42%
Total	19	100%
	Control Class	
Male	13	68%
Female	6	32%
Total	19	100%

2.3. Analysis Data

The creativity instrument is in the form of a Likert scale with ranges from 1 up to 5. After collecting the data, we converted the data in the form of percentages. The equation used is shown in Eq. (1).

$$P = \frac{f}{N} \times 100 \quad (1)$$

where *P* is the Percentage, *f* is the Score gained, and *N* is the Maximum score (Rockyane & Sukartiningsih, 2018).

The score converted then will undergo statistical measurement likewise the objective test instrument. The N-Gain score becomes the parameter to describe the result of the questionnaire. To calculate the N-Gain score, we used Eq. (2).

$$g = \frac{post\ test\ score - pre\ test\ score}{maximum\ possible\ score - pre\ test\ score} \quad (2)$$

where *g* is the N-Gain score (Meltzer, 2002).

The N-Gain score has categories to describe the data. This category of N-Gain score is presented in **Table 3**. The N-Gain category score as shown in **Table 3** will be used to interpret the N-Gain score. Thus, we can draw a conclusion based on the results. Mann-Whitney U test will be used to see whether there is a significant difference in students' creativity post-test between the experimental class and the control class (H_1) or if there is no significant difference in students' creativity post-test between the experiment and control class (H_0).

Table 3. N-Gain score category.

N-Gain Score	Category
g > 0.3	Low
0.3 ≤ g ≤ 0.7	Medium
g > 0.7	High

2.4. Research Procedure

The research procedure started with the preparation stage in which the research problem. The stage is to continue to prepare the instruments of students' creativity. Next, the instrument will be validated by the expert judgment and directly revised. The last thing to do in this stage is to make a lesson plan along with other learning media needed. There are 3 meetings of lessons in each class excluding the pre-test and post-test activities. The second research procedure namely the implementation stage consists of doing the implementation in the class and giving students pre-tests and post-tests under the permission of the school. The third step is the completion stage. We collected and calculated the data to further analyze the data and find the result.

3. RESULTS AND DISCUSSION

3.1. The Effect of STEM-Engineering Design Process on Students' Creativity

The students' creativity was measured with a questionnaire that was adapted from Miller and Dumford (2014) consisting of 28 questionnaires in the form of a Likert Scale. A creativity questionnaire was conducted before and after the treatment in each class. The response options differ from (1) Never, (2) Rarely, (3) Sometimes, (4) Often, and (5) Always. There are six subscales of the creativity questionnaire which are idea manipulation, imagery/sensory, flow, metaphorical/analogical thinking, idea generation, and incubation. *Google Forms* was used as the media to spread out the questionnaire to the students. After completing the pre-test and post-test, the data will be analyzed statistically to know if is there any improvement in students' cognitive creativity before and after the treatment and significant difference between the two classes. As the first step in analyzing the data statistically, the average score, maximum score, and minimum score were measured to give brief information about the data as shown in **Table 4**.

Table 4. The recapitulation of students' creativity questionnaire.

Component	Pre-Test		Post-Test	
	Experiment Class	Control Class	Experiment Class	Control Class
N	19	19	19	19
Average Score	70.45%	71.73%	72.37%	72.44%
Maximum Score	80%	88.57%	82.14%	90%
Minimum Score	61.43%	60%	60.71%	57.86%

Table 4 shows the average score in the pre-test for the experiment class is 70.45% and increased by 1.92% score in the post-test to 72.37%. In the control class, the improvement of the average score from the pre-test to the post-test is 0.17% for the pre-test is 71.73%, and for the post-test is 72.44. The maximum score for the pre-test in the experiment class is 80% while in the control class is 88.57. For maximum score of post-test in the experiment and control class is 82.14 and 90%. Furthermore, the minimum score in the experiment class for pre-test and post-test sequentially is 61.43 and 60.71%. In the control class, the minimum score for pre-test and post-test is 60 and 57.86%. To more clearly see the comparison of average scores between the experiment class and control class before and after the treatment is shown in **Figure 1**.

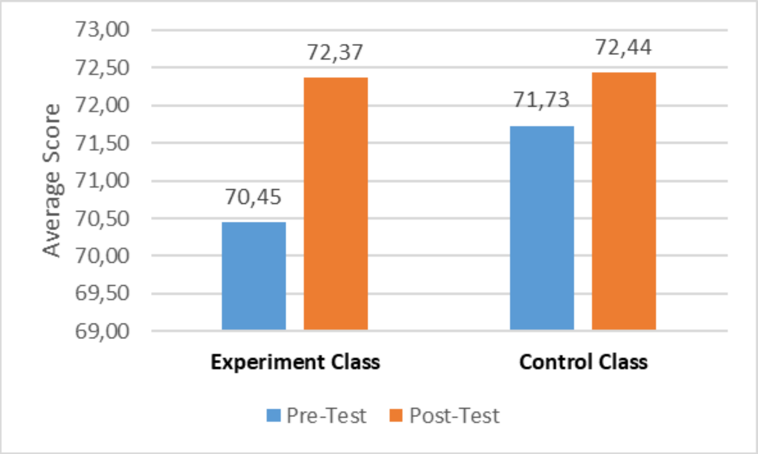

Figure 1. The comparison of creativity average score between experiment class and control class.

From **Figure 1**, we can see that there is an improvement between the pre-test and post-test. However, the improvement score in the experiment class was higher than in the control class even though the average score of the control class was higher than the experiment class in both pre-test and post-test. The normality test and homogeneity test are measured first as the prerequisite test of a hypothesis test. The result of the normality test in the pre-test and post-test between the experiment class and control class using the Shapiro-Wilk Test is shown in **Table 5**.

Table 5. Normality test result of students' creativity questionnaire.

Component	Pre-Test		Post-Test	
	Experiment Class	Control Class	Experiment Class	Control Class
Signification (Sig α=0.05)	0.24	0.25	0.42	0.6
Information	Normally Distributed	Normally Distributed	Normally Distributed	Normally Distributed

From **Table 5**, the normality score of the pre-test in the experiment class is 0.24 with $\alpha > 0.05$ indicating that the data is normally distributed as well as for the post-test with a normality score of 0.42. In control class also shows the same result for the pre-test and post-test, both data are normally distributed because the normality score is 0.25 and 0.6 with $\alpha > 0.05$. In experiment class for the post-test also shows the data is normally distributed since the normality score is 0.23 with $\alpha > 0.05$. The next prerequisite test is the homogeneity test using Levene Test which is presented in **Table 6**.

Table 6. Homogeneity test result of students' creativity questionnaire.

Component	Pre-Test		Post-Test	
	Experiment Class	Control Class	Experiment Class	Control Class
	Levene Test		Levene Test	
Signification (Sig α=0.05)	0.21		0.03	
Information	Data is homogenous		Data is heterogenous	

It is shown in **Table 6** that the data in the post-test between the experiment class and control class is not homogenous. The homogeneity score for the data is 0.03 with $\alpha < 0.05$. However, the data for the pre-test between the experiment class and control class is 0.21 with $\alpha > 0.05$ and it is indicated that the data is homogeny. Based on the result of the normality test and homogeneity test, we can use a non-parametric test for testing the hypothesis. Even though the data is normally distributed, one data is not homogeny which is the post-test between the experiment class and control class. Thus, the Mann-Whitney U Test will be used for the non-parametric test since the prerequisite test doesn't qualify parametric test as shown in **Table 7**.

Table 7. Mann-whitney U test result of students' creativity questionnaire.

Component	Pre-Test		Post-Test	
	Experiment Class	Control Class	Experiment Class	Control Class
	Mann-Whitney U Test		Mann-Whitney U Test	
Signification (Sig α=0.05)	0.76		0.77	
Information	H_0 accepted		H_0 accepted	
Conclusion	There is no significant difference		There is no significant difference	

Based on **Table 7**, there is no significant difference between the experiment class and control class whether in pre-test or post-test. The result of the Mann-Whitney U test in the pre-test between experiment and control class is 0.76 which is higher than the significant difference criteria (Sig. < 0.05). Thus, the H_0 is accepted and H_1 is rejected which means there is no significant difference between the experiment class and the control class after the treatment. The same result happened in the post-test between the experiment and control class with the sig. (2-tailed) is 0.77 which means there is no significant difference. Thus, H_0 will be accepted while H_1 is rejected. The N-Gain score of the comparison between the experiment class and the control class is shown in **Figure 2**.

According to **Figure 2**, the N-Gain score between the experiment class and the control class has quite a big difference with the experiment class being higher than the control class. As we can see, the N-Gain score in the experiment class is 0.06 while in the control class is 0.03. Even though the N-Gain of both classes is indicated as low improvement, there are still differences between the two classes. Even more, the experiment class has a higher improvement score than the control class. However, the improvement of the N-Gain score in the experiment class may affected based on the implementation of the engineering design process. Based on Han and Shim (2019) the engineering design process consists of defining the problem, gathering information, generating the solution, implementing the best solution, evaluating the best solution, and reflecting which is then abbreviated as the DIGIER. Creativity is the soft skill that is the most important for engineers to do engineering activities. In line with the definition of the engineering design process from Han and Shim (2019) is the process of creating a creative product to fit given restrictions and user needs by utilizing the designers' scientific, mathematical, and engineering skills. The engineering design process of the DIGIER model requires different types of creative components (Kozbelt *et al*., 2010; Miller & Dumford, 2016). However, this research only focuses on students' cognitive creativity which involves the creative component of "process".

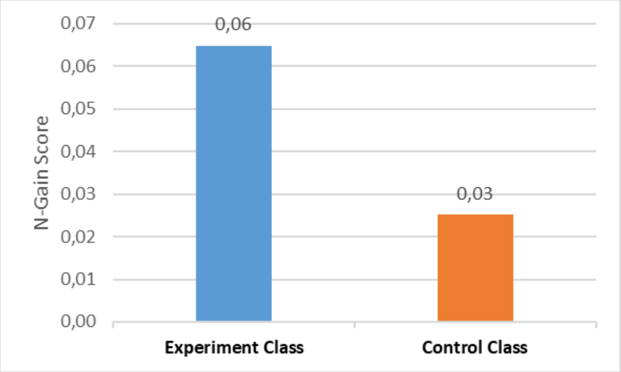

Figure 2. Comparison of creativity N-Gain score between experiment class and control class.

As for "process" the creative component occurred in the first stage of the engineering design process when students defined the problem, they were given an open-ended question that related to real real-life problem. Based on Daly *et al*. (2014), open-ended projects in engineering education are a common instructional that allows creative opportunities. The project is the solution to the problem and students generate the solution within the group. The second stage is ingathering information where students look at the various solutions from different sources on the internet will affect their creative thinking in solving the problem. Generating the solution in the third step of the engineering design process requires the creative thinking most (Denson 2015; Altan & Tan, 2020) where students have to develop ideas as many as possible under the constraints and criteria needed. Students also transferred their ideas into the initial design by sketching or drawing them in their worksheets. The initial and final design from the representative group can be shown in **Figure 3**.

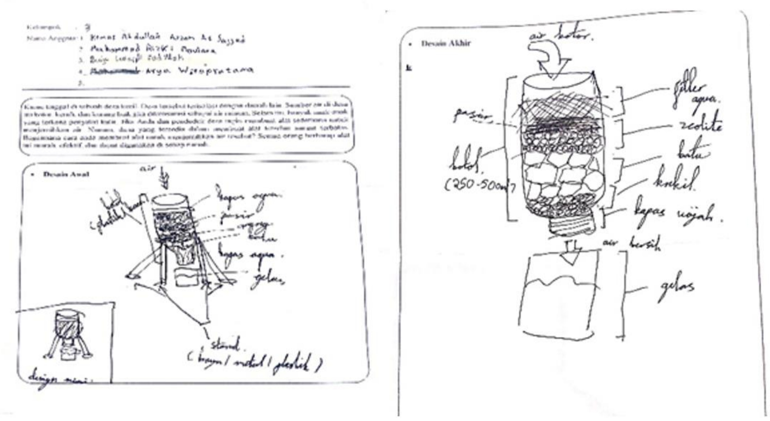

Figure 3. Initial and final design of water filtration.

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Communication, in this stage, occurred as well when students presented their initial design to give and receive feedback from other students. In line with the study conducted by Cropley and Cropley (2000) in engineering undergraduates that resulted in higher creativity after receiving feedback rather than students who did not participate in feedback sessions (Daly *et al*., 2014). The fourth stage, implementing the best solution, requires students to choose the best solution after receiving feedback from other students and making the real product based on the design. In this stage, students need their creativity to transform the design into a real product. The final stage is evaluating the best solution and reflecting where students test their water filtration tool to assess whether it is fulfilling the hypothesis or not and finding the reason why their product proves the hypothesis or why it does not. The previous studies in line with this result conducted by Conradty and Bogner (2018) on how to monitor creativity using 8 items Likert-scale questionnaire that consists of two subscales, Act (covering conscious and trainable cognitive processes) and Flow (a mental state of creativity) showed that younger's student's creativity score was higher than the older students and there was no difference in gender. Altan and Tan (2020) in their study stated that making prototypes, other students' ideas, and the degree of familiarity with the design-based learning process are the things that influenced the creativity of students' ideas. The scientific creativity of 9th-grade students in Eroglu and Bektas (2022) between the experiment and control group has significant differences after STEM application in favor of experiment class.

The study conducted by Huang *et al*. (2020) concluded that between creative thinking, psychomotor skills, and creative self-efficacy (CSE), the skill that has the highest score of effect on engineering design creativity is students' creative self-efficacy (CSE), followed by creative thinking and psychomotor skills. A systematic literature review from Aguilera and Ortiz-Revilla (2021) found that both STEM and STEAM education approach shows positive evidence in student creativity. Avsec and Savec (2019) researched creativity and critical thinking in engineering design and showed that the synergy of creativity and critical thinking is enhanced in design ideation by connecting interdisciplinary augmentation with teacher education. Hathcock *et al*. (2015) investigated the use of inquiry-based questioning as a technique of encouraging creativity within a design-based STEM activity and found groups aided by inquiry-based questioning strategy were better able to solve an ill-structured problem and accomplished a more linear development toward creative output than groups aided by non-inquiry-based questions. Another research from Anh *et al*. (2022) that showed STEM clubs demonstrate a significant impact on students' creativity. Daly *et al*. (2014) discovered that one aspect of creativity, convergent thinking (including analysis and evaluation), was well represented in the engineering courses. Starkey *et al*. (2016) researched how creative ideas are promoted or filtered throughout the design process to focus educational efforts and the result provides empirical evidence for differences in novelty and creativity at all stages of the design process for different design tasks. However, the result shows there is no significant difference between the experiment and control class in students' creativity because both classes made the same project. Nonetheless, the experiment class gets a higher score of N-Gain than the control class because of the implementation of the engineering design process in the experiment class.

3.2. The Effect of STEM-Engineering Design Process on Students' Creativity on Each Subscale

Based on Miller (2014), there are six subscales of creativity, which are idea manipulation, imagery/sensory, flow, metaphorical/ analogical thinking, idea generation, and incubation. All subscales will be analyzed statistically one by one. The recapitulation score of students' creativity on each subscale is shown in **Table 8**.

Table 8. The recapitulation score of students' creativity on each subscale.

Class	**Component**	**Creativity Subscale**											
		Idea Manipulation		**Imagery / Sensory**		**Flow**		**Metaphorical / Analogical Thinking**		**Idea Generation**		**Incubation**	
		Pre-Test	**Post-Test**	**Pre-Test**	**Post-Test**	**Pre-Test**	**Post-Test**	**Pre-Test**	**Post-Test**	**Pre-Test**	**Post-Test**	**Pre-Test**	**Post-Test**
Experiment	X	74%	75%	71%	75%	72%	76%	68%	72%	71%	71%	63%	61%
	Gain	1		4		4		4		0		-2	
	N-Gain	0.06		0.13		0.13		0.1		0.01		-0.05	
	N-Gain Category	Low		Low		Low		Low		Low		Low	
Control Class	X	75%	75%	74%	75%	75%	77%	70%	71%	71%	72%	61%	60%
	Gain	0		1		2		1		1		-1	
	N-Gain	0.01		0.03		0.07		0.04		0.04		-0.03	
	N-Gain Category	Low		Low		Low		Low		Low		Low	
Mann-Whitney U Test		0.7	1	0.4	0.9	0.4	1	0.68	0.55	0.7	0.9	0.7	0.7
Information		No Significant											

From **Table 8**, the average score of pre-test and post-test in the experiment and control class on each subscale mostly shows improvement even though just a few scores. But there are also subscales which did not increase at all and even decreased. As we can see on the idea generation subscale in the experiment class, there is no improvement due to the same result of pre-test and post-test. Likewise the idea manipulation subscale in the control class. The reduction of average scores between the pre-test and post-test also happened on the incubation subscale either in the experiment or control class. The post-test score in the subscale is lower than the pre-test score. The average score will affect the N-Gain score. To see the comparison of the N-Gain score between the experiment class and control class in each subscale, see **Figure 4**.

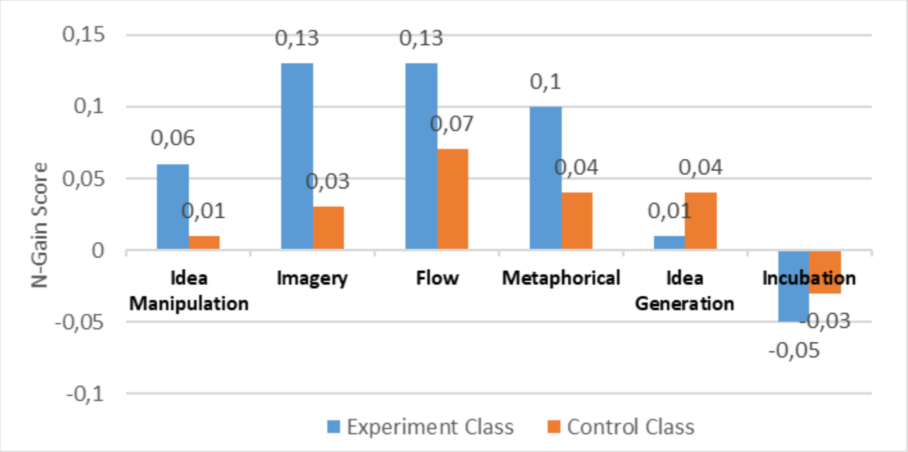

Figure 4. Comparison of N-Gain score between experiment class and control class in each subscale.

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Based on **Figure 4**, the N-Gain score of all subscales is categorized as low improvement because there are only a few improvements in the average score between the pre-test and post-test. Still, following the average score, the subscale that has no improvement is the idea manipulation subscale for the control class and the idea generation subscale for the experiment class. The N-Gain score of the two subscales is 0.01 which is near to 0. The subscale that is decreased in its post-test score is the incubation subscale resulting minus score of the N-Gain. Among all scores on each sub-scales for the experiment class, the highest score is obtained in the imagery/sensory and flow sub-scales. The lowest score occurred in the incubation sub-scale. Comparing the experiment class with the control class, almost all sub-scales of creativity in the experiment class are higher than the control class except for idea generation and incubation. Imagery sub-scale is conceptualized as any type of sensory modality not only internal mental sensations of a visual nature (Miller, 2014). The engineering design process requires students to use their senses to solve the problem such as collecting the information students use auditory and vision to watch some videos or read some articles. Also when students make the prototype, students use tactic sensory in choosing the materials that are best to make the water filtration tool. This is following Miller (2014) creativity is not simply conveyed visually, linking imagery to the creative process should also include auditory, tactile, kinaesthetic, and other sensory channels.

Idea generation occurs in the stage of ingathering information about the engineering design process that has been implemented in this research. During this stage, students generate the solution as much as possible with the help of technology. The low score in this sub-scale can be affected by the implementation of this 2nd stage of the engineering design process. Due to the limitation of time when this stage was implemented, students were forced to hurriedly find the solution to the problem given. This action might be impactful in students' idea generation. Because of the rush, students could not generate the solution as much as it should be. Another factor that influenced the low score in idea generation is that the class environment did not support the engineering activity. The class was too small for its size and students did not have a lot of space left between each other. This position allows exposure to other students' ideas that affect one another. These reasons are supported by the previous study as already stated before in Altan and Tan (2020) several factors influenced the creativity of the student's ideas, including exposure to other students' ideas, the degree of familiarity with the design-based learning process, and the requirement that students create a working prototype of their ideas.

Likewise, the result from Jindal-Snape *et al.* (2013) found that the structure of a classroom had an impact on students to demonstrate the ability of creativity. Starkey *et al.* (2016) regardless of the design objective under consideration, there was a decrease in the creativity of student design ideas from the idea-generating stage to the students' final conceptual design. In addition, the lack of materials in the engineering context, limited time to conduct the creativity process, and lack of instructor's ability to support students in creativity skills are the several things that become the challenges in engineering programs (Felder, 1987; see http://www.nspe.org/PEmagazine/pe_0808_Dispelling.html; Kazerounian & Foley, 2007; Klukken *et al.*, 1997; Tolbert & Daly, 2013; Daly *et al.*, 2014). Meanwhile, flow is defined as an ''almost automatic, effortless, yet highly focused state of consciousness'' that occurs when an individual is engaged in intense work, often of a creative nature (Miller, 2014). The high score can be assumed that students are enjoying the engineering design process.

Incubation can be defined as a ''period of preconscious, fringe conscious, off-conscious, or even unconscious mental activity'' that occurs while the thinker is engaged in other (typically normal) activities (Miller, 2014). The questionnaire item includes in the incubation sub-scale that most shows the reduction in the average score is the item with the question "I get solutions to problems when my mind is relaxed". The reason behind this is that students have difficulty understanding the words in the questionnaire. This also discusses the future directions in Miller (2014) that the questionnaire items were initially written for an adult level of reading comprehension. Contrast with the population of this research which consists of students in the ages range from 15 to 16 years old.

Moreover, students received the questionnaire items in Indonesian language that were translated. At this point, our ability to deliver the meaning of the questionnaire items is lacking. Besides that, incubation is the process of thinking while students are engaged in daily activities making students not sure what they were thinking during those times also becomes the reason why students got the lowest score in the incubation sub-scale. The study of creative incubation mostly relating the process of mind wandering. Such as Murray *et al.* (2021 see . https://doi.org/10.1037/aca0000420) that was conducted research on the benefits of mind wandering to creativity backgrounded by a few studies that suggested mind wandering is beneficial during creative-incubation interval and facilitates creative thinking. However, their study shows there is no evidence to support the concept that mind wandering during a creative incubation interval promotes a type of creativity known as divergent thinking. Another study investigates the relationship between idea generation and freely moving mind wandering during boring versus engaging video tasks. Their finding is mind wandering leads to more creative ideas, but only when the activity is fairly stimulating.

According to this response, the low in students' incubation is due to less engaging activity during the engineering design process. In addition, a study by Tan *et al.* (2015) identified whether insightful solutions were related to mind wandering during the incubation stage of the creative process using the number reduction task (NRT) resulted that the students who are problem solvers significantly more mind wandering during incubation than those who are not a problem solver. Relating this, the students in this research were working in a group which is likely only a few people who do problem solving. Therefore, incubation in both classes was low.

4. CONCLUSION

The result of students' creativity, there is no significant difference between the experiment and control class in both pre-test and post-test. However, the N-Gain score showed there is an improvement between the pre-test and post-test in creativity. The score from each sub-scale analysis showed the highest N-Gain score in the experiment class is imagery and flow with 0.13 indicating a low improvement. As for the control class, the highest score occurred in the flow sub-scale with a 0.07 N-Gain score described as a low improvement. The lowest score of students' creativity on each sub-scale scale was obtained from incubation with -0.05 in the experiment class and -0.03 in the control class. This result indicates there is no improvement and even can be described as a decreasing score of pre-test to post-test. The minus score in the experiment class is higher than in the control class means that the experiment class gets a lower score than the control class. The implementation of the engineering design process does not enhance significantly the creativity of students. From these results, we would allow future researchers to gain more participants and get more precise data, discuss with the teacher about the results, make sure the materials and equipment needed can be provided, and maximize the time given as best as possible to conduct the research.

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6. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. The authors confirmed that the paper was free of plagiarism.

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