

Building Creativity Beyond the Classroom: The 4DFrame After-School Experience in Bandung, Indonesia

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ABSTRACT

Creativity is an important life skill but is often underemphasized in formal education due to curriculum limitations. Extra-curricular programs can provide alternative opportunities to develop these skills. This study aims to analyze the learning process and creativity outcomes of the Young STEM Program using 4DFrame as learning media. A descriptive study was conducted involving 17 students who participated in this after-school program for three months. Student creativity was assessed based on a product design worksheet and final product using rubric adapted from Torrance framework, which includes 4 aspects namely fluency, flexibility, originality, and elaboration. The result showed an increase in overall creativity, especially in the aspect of fluency and elaboration, as evidenced by a shift in student's performance from lower to higher rubric categories. By the final topic, 71% of students reached an excellent level in fluency, while all students achieved at least a good level in elaboration. Meanwhile, flexibility and originality aspects are still varying depending on the topic given. These findings suggest that structured extracurricular/after-school STEM activities using tools such as 4DFrame can support the development of specific aspects of student creativity.

Keywords: 4DFrame, After-school program, Creativity, STEM education

Introduction

& Hagul, 2001) Education in the 21st century is not enough just by teaching the content of subject matter to students (Wijaya et al., 2016). The paces that are rapidly changing due to the rapid development of technology always demand innovation. Meanwhile, to be able to innovate requires creativity (Nakano & Wechsler, 2018; Robinson, 2012). Creativity is an activity or thinking style that characteristically generates innovative ideas, procedures, or products that are novel in order to solve problems and give benefits to oneself or the community (Wu et al., 2018). The international community, like the OECD, even started in 2022 to include creativity (or creative thinking) in their PISA framework to emphasize that creative and innovative learning environments are urgent to address emerging challenges (Popkewitz, 2022). However, it is unfortunate that this creativity is often put aside in schools because schools are more focused on pursuing the demands of the curriculum and achieving high score on the exam (Carroll, 2013; Jusuf et al., 2020; Mccarthy & Blake, 2017) For example in Indonesia, the national curriculum often emphasizes rote memorization and standardized testing, leaving limited room for creative exploration and divergent thinking practices. Of course this fact is somewhat at odds with global demands.

The existing literature clearly emphasizes the potential of hands-on, inquiry-based teaching in fostering these skills (Prince, 2004; van Uum et al., 2016). Specifically, the integration of Science, Technology, Engineering, and Mathematics (STEM) education has emerged as an interdisciplinary approach that naturally encourages critical thinking, creativity, and practical learning (Bybee, 2010; National Research Council, 2011).

One alternative way to practice skills or life skills is through the after-school program (Smith & Bradshaw, 2017). Earlier studies reported that after-school programs have a positive impact on adolescents' life skills development, like social skills, problem-solving, and sense of purpose (Lee et al., 2017). Furthermore, significant meta-analyses confirm their efficacy in improving personal skills like self-control and relationship skills, which are vital for overall youth development (Durlak & Weissberg, 2007).

While the benefits of STEM education and after-school programs are well-documented individually, there remains a relative lack of research that specifically examines the effectiveness of structured STEM-focused after-school programs in fostering creativity and problem-solving skills, especially in contexts where formal education limits such opportunities. Moreover, despite the increasing availability of innovative educational tools, studies on their specific impact within these after-school settings are still emerging. However, this method is less popular, especially in Bandung. After-school program institutions are actually dominated by tutoring institutions, which are equally focused on exam/test results.

The 4DFrame-STEM education center UPI, which initially only showed displays/introduced 4DFrames to visitors, was finally moved to start opening an afterschool activity called a Young STEM Program. This initiative directly addresses the identified need for alternative learning environments that prioritize skill development over memorization in the local context. The program activity focuses on practicing problem-solving skills as well as creativity through a STEM approach using 4DFrame as learning media.

4DFrame is an educational tool that originated from South Korea and is made of plastic with 2 basic components: connectors and tubes. This component can be connected and/or combined to form figures, various polyhedrons, creative pieces, and virtually anything (I & Back, 2015). 4DFrame has some features, such as free bending, diverse angle adjustment, and easy cutting/shaping using only a scissor, that make this tool very versatile for fast prototyping, creative modeling, and creative learning. Given these unique features, 4DFrame presents a promising yet underexplored medium for fostering creative problem-solving in a hands-on STEM context. While previous studies have acknowledged its potential for spatial reasoning and design (Ju et al., 2022), there is a limited understanding of its feature in developing creativity skills when implemented as part of a structured after-school STEM program in the Indonesian context. Therefore, this study aims to analyze the process and outcomes of the Young STEM Program, utilizing 4DFrame as the primary educational tool, in fostering creativity among its participants.

Methods

This study involved 17 students from grades 4-7 (average age = 11 years). Participants who took part were students of the creativity class of the Young STEM Program. This class consists of 8 boys and 9 girls. It is an after-school learning program that we hold every

Saturday, every 2 weeks, from 9 am to 3 pm. The activity was held at the museum in the university, but the outbreak in Indonesia caused the activity to be delayed and finally continued through a Zoom meeting in the middle of the process. The learning system focuses on how students can think critically and creatively to solve challenges on each theme/topic that we provided using 4DFrame as a learning media. For 3 months we presented 4 themes, namely catapults, automata, bridges, and rolling balls. At the end of the meeting, we asked the children to hold an exhibition in front of their parents, teachers, and friends. However, due to the situation, activities were held via Zoom without changing the topic, but this situation had enough impact on how teamwork is carried out and products are tested especially for rolling ball topics, so we exclude this topic. We limit the creativity that we measure to the creativity of ideas and design creativity related to the solutions that students present for each topic/theme that we provide.

Each topic was opened by giving an issue related to the challenges that students needed to solve, and then there was a little concept related to that topic. Then after that, students will be asked to fill out a worksheet that contains questions related to what ideas they have, as well as how the design of the products they will make is. After that, they will work in groups of 2 people when making products. The products they have made are then presented in front of the class while answering certain questions. However, when the outbreak happened in Indonesia, we were forced to suspend class. And because it didn't get better, we were forced to continue the class through the Zoom meeting.

The research data was taken from the product design on the worksheet that the students worked on. Data analysis was conducted through rubric-based qualitative descriptive analysis. Students' answers and designs were evaluated using a creativity rubric that has been previously made. This rubric was made to adapt Torrance's creative aspects, namely fluency, flexibility, originality, and elaboration (Runco et al., 2010). Each aspect of creativity was analyzed to identify patterns and variations in students' creative performance. The results were interpreted by relating rubric scores with observable characteristics of student designs and/or products. The lowest score is 1 (poor), and the maximum score is 4 (excellent). For more details, the rubric of the assessment can be seen in the following table.

Table 1. Rubric for assessing the creativity of student's ideas and designs

Aspect	Criteria and Descriptor			
	Poor	Fair	Good	Excellent
Fluency	Propose only one idea, no detail design	Propose small number of idea and/or less detailed designs	Propose numbers of idea and/or detailed designs	Propose a large number of idea, more detail design
Flexibility	Propose classic idea and design	Propose rigid idea and/or design	Propose a variety ideas and designs	Combine variety of ideas and designs
Originality	Idea, design is same as other group	Idea and design have less common with other group	Idea and/or design is less expected from other group without neglecting basic principle	Idea and/or design is most unique from other group without neglecting basic principle
Elaboration	Idea & design doesn't include any details	With some assistance idea can be expanded; design can be embellished	Add more details and making changes to the original ideas/design	Ideas/designs are well-developed and detailed

Results and Discussion

The first theme discussed during the lesson was about energy. The topic raised this time was about catapults. Students are asked to design a catapult using a 4DFrame that can shoot a ping pong ball towards a target at a certain distance. They need to design and think about what kind of structure is strong enough to support the catapult, what kind of ejection mechanism provides enough power to hit the target, and what is the optimum elevation angle for a balanced height and distance. Some students gave the following ideas: Student team (2): "We want to make a catapult according to our imagination. With a size of 60x60 (cm). And it must hit the target. And we have to measure the distance. And we made a catapult with 2 people." Student team (5): "I see. We will follow the existing ones and keep changing so that we can be creative." Student team (6): "We will make a catapult with arms that are not too long or short. We will make a catapult with the thrower not too big and small." Student team (7): "The front of the catapult must be heavy. The bottom of the catapult must be strong. The angle is made to taper. The tip of the arm must be sufficient with the ball. Using a strong straw." Here it can be seen that there are groups of students who are able to provide good reasoning, and there are also those who are not able to do that. Figure 1 is the picture that shows the design of the group that answered above, and beside that, Figure 2 shows the product that students made using 4DFrame.

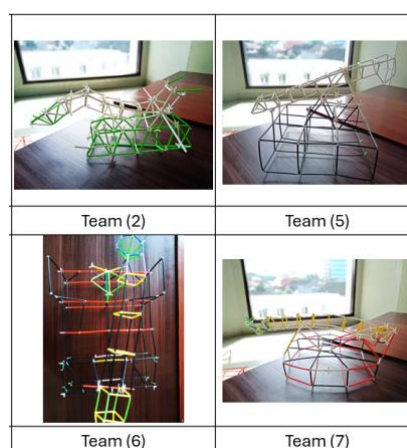
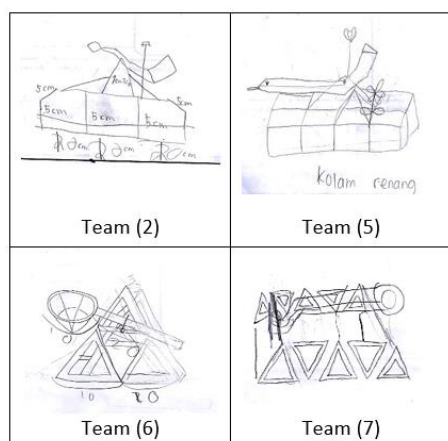


Fig. 1. Students' Catapult Design Fig. 2. Student's Catapult Product using 4DFrame

From Figure 1 and Figure 2, there are some groups that can build the product same as their design by using 4DFrame, and there are also groups that can't do that, like representatives from Team 6 and Team 7. This difference is common in assessing creativity. Because there are many factors that can lead to the design of a product differ from the final product (Abdellatif & El-Wakeel, 2025; Shively et al., 2018).

The next theme was automata. Automata or automaton generally refers to mechanical objects or devices that can move or perform actions automatically, often driven by a mechanism like a crank or gears. These devices mimic the movements of humans, animals, or other objects and can be used for entertainment or storytelling (Gulizia, 2016; Natale, 2024; Semmerling et al., 2018). In this topic, each student was asked to make a figure/machine that could move on its own. There are no restrictions on creating these automata. The ideas put forward by students also vary; for example, student team (3): "We will make the clamp automata. The part that will

move is the clamp. My friend and I will make the clamp automata using 4DFrame. The reason is to make it easier to retrieve goods. And automata are something that moves with its own will". Student team (6): "We are going to make a waterwheel. The waterwheel will move using a gear; what will move is the wheel. We are making a waterwheel because we are inspired by a helicopter. And we are also interested in making a waterwheel. The rotating gear will move the gear on". Student team (8): "My friend and I will make a crocodile. The crocodile can open and close its mouth. The crocodile is green. The height is less than 30. The length is less than 30." It can be seen from the examples of these answers that each group has a different idea; even some students have been able to give the purpose of what they are going to make. This is a positive thing for them. The designs of these three groups of students can be seen below in figure 3.

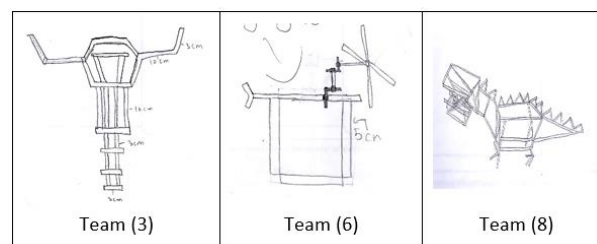


Fig. 3. Students' Automata Design

The next theme raised is bridge, and one of the reasons why this theme was raised is because there are so many regions in Indonesia that are connected by bridges to support the economy in the area. Unfortunately, there are still many bridges that are inadequate, threatening the lives of their users and potentially hindering the development of the two connected areas. In this theme, students are asked to build a strong bridge to help transportation in areas that are in need. The bridge prototype is made out of 4DFrame, with a max length of 60 cm, and must be able to support a load of at least 500 grams. Some students gave ideas to answer this challenge as follows: student team (1): "The types of bridges that we make are arch and truss. The name of our bridge is 'Bridges'. We made this bridge because this bridge is unique and must be strong. This bridge combines 2 designs. We chose this design because of its unique and strong triangular and circular structure. " Student team (2) "First you need a strong support, then it needs to be tight. We made this bridge because this model seems like it's strong and healthy, there is a triangle because stable and a strong support". Student team (4) "Today I will make a bridge. With a triangle shape. I made a triangle shape because I believe that the triangle is strong. They said the triangle is the strongest flat shape. That's why we are currently making a triangle bridge". Student team (5) "Today we will make London bridge. We will make a wide bridge. We can do it, we will try it. Because London bridge is strong". It can be seen in the examples of these answers that several groups of students have similarities. Likewise, the bridge design also experiences similarities. Figure 4 shows the students' design on making a bridge.

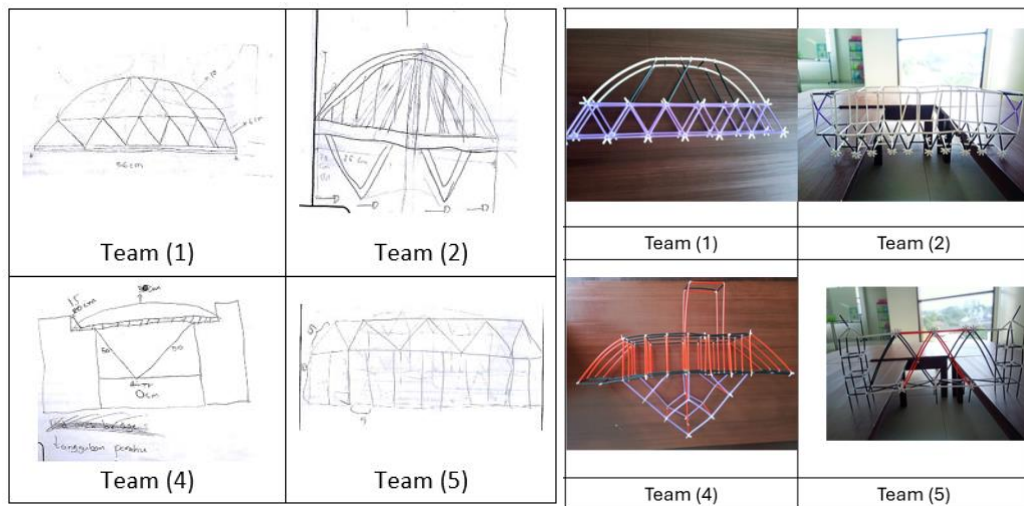


Fig. 4. Students; bridge design and product

Based on the assessment result from their worksheet that the students' did on each topic, we try to analyze students' creativity based on Torrance creativity aspect which is fluency, flexibility, originality and elaboration. Using the rubric from table 1, we analyze the creativity of student design. The result is shown in Figure 5 below.

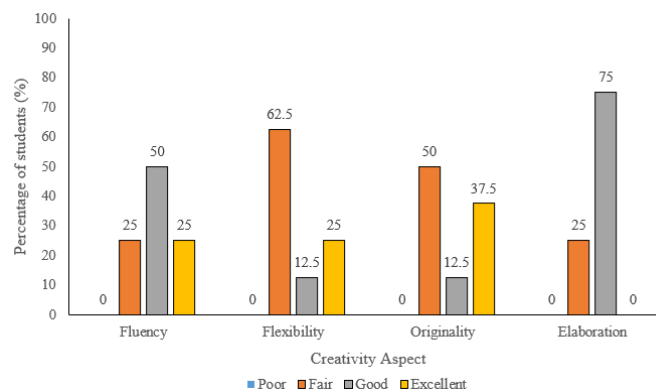


Fig 5. Distribution of Student Group Creativity Levels by Aspect in Catapult Topic

From the graph above, there is no single group of students that has poor criteria in the creative aspect; hence, this is their first time joining the STEM class. Only 37 percent were able to achieve excellent scores in the originality aspect, while flexibility and fluency were only 25 percent of students who were able to achieve excellent scores. No students achieved excellence in the elaboration aspect. Most students are distributed in the fair to good categories. The highest percentage of the good category is in the elaboration aspect, while the highest fair is in the flexibility aspect. This shows that student designs are still limited to the flexibility aspect, where they are still too rigid to think of something out-of-the-box, that an object called a catapult must have that shape even though there are absolutely no limitations regarding the designs that are allowed. This also affects the assessment of the originality aspect because the catapult design between groups will tend to be the same (this can be seen in Figure 2) so that 50% of student groups fall into the fair category. This finding is our basis to design the next learning activities. Student result in second topic (automata) can be seen in the following figure

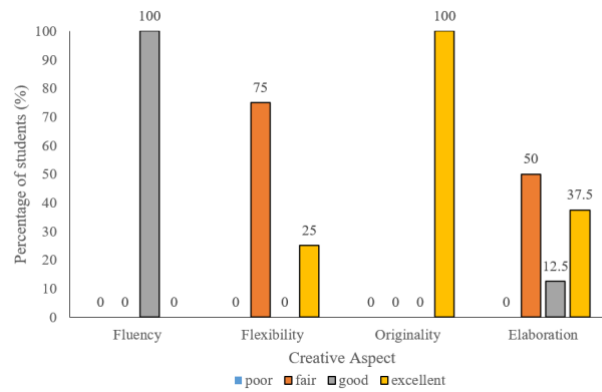


Fig 6. Distribution of Student Group Creativity Levels by Aspect in Automata Topic

From the graph above, there is still no group that falls into the "poor" category even though this topic has a different level of difficulty from the previous topic. The highest score is in originality because every single group gives a unique idea, and no one group has the same design in this automata topic, so they are given the maximum score in originality. Meanwhile, in the fluency aspect, all students are in the good category. However, for the flexibility aspect, 75% of students are still in the fair category even though 25% have received excellent scores. On the other hand, student abilities to elaborate on their design spread from fair to excellent, with most groups in the fair category. This result could have occurred because there are so many examples of products that use the principle of automata to attract people's attention, so the more examples in the real world, the more options students can choose from, thus differentiating their work results from other groups (Han et al., 2022; Kuzmickaja et al., 2015; McInerney, 2023). Student results in the third topic (bridge) can be seen in the Figure 7 below.

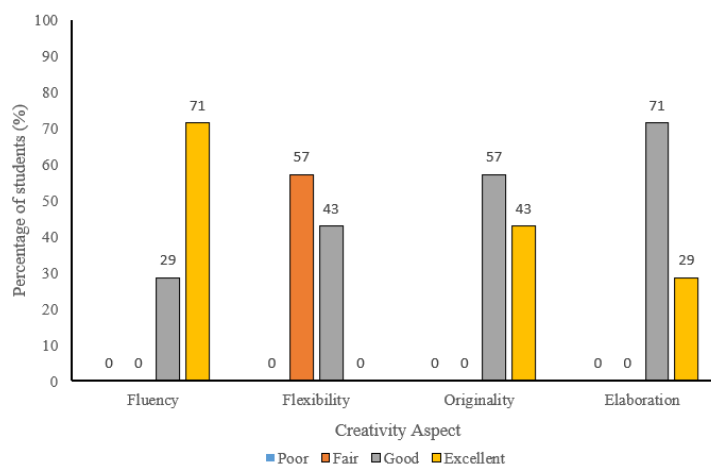


Fig 7. Distribution of Student Group Creativity Levels by Aspect in Bridge Topic

From the graph above, until the third topic, there is not a single group that enters the poor category. In fact, there are 3 aspects of creativity that no students enter the fair category, namely fluency, originality, and elaboration. The aspect of creativity with the highest excellent score is fluency, with 71% of student groups getting excellent scores, then originality with 43% and elaboration with 29%. Meanwhile, flexibility is the only aspect where there are still groups of students with the fair category, even 57% of students enter this category. This result may be influenced by several factors, as explained by other researchers that flexibility takes longer to

develop and is more uneven than other creative aspects (Beaty & Silvia, 2012). This can happen due to the scoring rubric (Silvia et al., 2008) or because the cognitive process involving flexibility requires cognitive control and switching between categories, which is cognitively more demanding than generating many ideas (fluency) (Beaty et al., 2015).

Results of this study indeed do not show strong evidence through students' improvement in creativity. But we found that there is much potential to improve students' creativity through this program. There are several factors that might influence the result, such as students' seriousness in filling out the worksheet. Sometimes they give a minimal answer compared to their capability, even though the products they make are much better than that. In this study we also found that it is not certain that a group with a good design will also have a good product execution, and it is not certain that a group that fills in improperly will also produce a modest product. Good collaboration often comes from groups of students who have wild ideas and then pair up with students who are able to accommodate their friends' imaginations. Often groups where the two members are very creative are actually not good at filling out worksheets. There are many factors that need to be explored further. In addition, the third meeting was the time when the outbreak started in Bandung, so there were instructions from the university to postpone/disperse activities that were to gather people. Student activities have to be completed early, which messes with the learning patterns we provide, but this needs to be taken to prevent the spread of the virus, so the remainder of the meeting will be held online. This sudden change in situation also has quite a lot of impact on the way of teaching and the way students respond to lessons. Because after all, the learning situation has changed.

Conclusion

The results obtained indicate that the afterschool program using 4DFrame in the Young STEM program was able to improve children's creativity. Judging from the overall aspects of creativity assessed as well as from the three learning topics given, it is evident that there is a tendency to experience an increase, especially in the aspect of fluency in creating ideas and the ability to elaborate on these ideas in more detail. But apparently, for the aspects of flexibility and originality, it still depends on the topic given.

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