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The implementation of project-based learning in STEM activity (water filtration system) in improving creative thinking skill

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The implementation of project-based learning in STEM activity (water filtration system) in improving creative thinking skill

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Abstract. This research is concerned with STEM activity making water purifier filter. The experiment class applies project-based learning, while the traditional class is taught using conventional teacher talk or explanation. This research used triangulation methods. The quantitative methods were applied to analyze student achievement tests according to creative thinking skills in making water filtration design. The qualitative method was applied using observation of student activity, presentations, and interviews for selected students. The student achievement test was analyzed and coupled with pretest and post-test quasi-experimental research. The collected data were analyzed using inferential statistics in the form of an independent sample *t-test* to express creative thinking skills. The result of the pre-test indicated the sig (2-tailed) of 0.965, with a significant value of 5% ($p>0.05$). This result indicated two classes were homogenous. The data analysis of the post-test indicated value of sig (2-tailed) 0.00 where $p\leq0.05$, which implied the student achievement test on creative thinking skills criteria in the experimental class was better than that in the control class.

1. Introduction

The 21st century leads us to focus attention on the dynamic change of the world. The global issues, climate changes, industrial, and huge economic development become the trigger for better education to prepare the next generation of the country [1.2]. Those problems facing today's society mostly emerged from science, technology, engineering, and mathematics. The STEM (Science, Technology, Engineering, and Mathematics) education potentially benefits for individuals and for the nation [3].

STEM education is an interdisciplinary approach to learn science, technology, engineering, and mathematics in contexts that enabling literacy [4]. Science is the knowledge about the world and its phenomena together with the behavior to get the rationalization about the natural phenomena. Technology is about how something can be used or applied based on practical knowledge [5]. Engineering is the logic and the technique used to design and construct something that works with some systems. Mathematic is the knowledge about the numbers, symbols, formulas, and the relationships among the quantities with the exact precision [6]. STEM points the way students thinking about real-life problems. The students that learn the STEM concept obtain the chance to enhance their thinking skills relate to solving the problems by doing the learning activities [7].

One of the most suitable instructional practices for 21st-century teaching is Project-Based Learning (PBL). PBL is an instructional model that promotes the real-world problem as the project to engage the learning content to the students in the context of solving the problem on the cooperative work situation. Learning activities through the PBL spark the students' motivation in learning and teamwork

that will also increase the collaborative skills of the students. In general, the instructional approach in project-based learning consists of some activities of students to finish the problem given. In PBL, students need to identify and seek the important thing to solve the problem, demonstrate their knowledge by developing the various project, and communicate their solutions for the problem to the others [8]. PBL presents the contextual and genuine experiences for students to construct the good concepts of science, technology, engineering, and mathematics. Furthermore, project-based learning in STEM can stimulate students to critically and analytically think that can improve the higher-order thinking skills of students [9].

Creative thinking is one of the skills that students need to had to face the 21st-century competencies [10.11]. Creative thinking represents the ability of the cognitive process to generate a novel idea through fluency, flexibility, originality, and elaboration thinking [12.13]. According to Sternberg and Lubart in [14], creative thinking is the ability to generate novel, excellence, and good ideas. Creative thinking skills highly related to divergent thinking, which is also underlying the creative thinking itself. Divergent thinking is the ability to generate some unique ideas as the solution of the given condition composed of fluency, flexibility, originality, and elaboration ability [15]. Standardized divergent thinking test designed to assess creativity with the criteria of fluency (generate many ideas). The flexibility (generate various ideas), originality (generate uncommon ideas), and elaboration (develop an idea by adding the details) [16]. Creativity should be educated in the socio-cultural environment, which is present in the inquiry science in the class [13]. Through STEM education, creativity can be fostered in the inquiry environment of the activities [17].

The reduction of water resources becomes the concern of almost every country in this world. The increasing global water consumption that much higher than the growth of the human population leads to a huge lack of safe drinking water [18]. The main potable water sources are from surface water, groundwater, and the groundwater that directly influenced by surface water, such as shallow wells. The surface water originally formed by the precipitation of rainfall or snow, which commonly easy to find and is not tainted minerally by the earth's coat. Along with the easy access of surface water, it has the disadvantages of easily contaminated by microorganisms and chemical pollutions [19].

Improving water quality present both socially and economically beneficial for every country. Water purification becomes the solution to remove the main pollution from most water sources so that the clean water can be provided [20]. Safe drinking water is the water that does not indicate any significant health risk over a lifetime consumption in any life stage. Therefore safe-drinking water has some indication including acceptable in taste, odor, and appearance. The optimum pH required for drinking-water usually in the 6.5-8.5 range to provide the stability of water and minimize the corrosion that may be occur. The ideal drinking-water should have no visible color, which most people can detect color above 15 true color units (TCU) so that the safe-drinking water levels color should below 15 TCU. The acceptable taste of drinking-water normally in a total dissolved solids (TDS) level of less than about 600 mg/l and become significantly not good at the TDS level above 1000 mg/l. The turbidity in water caused by precipitated particles or colloidal matter is measured in nephelometric turbidity units (NTU), which in the level above 4.0 NTU is visible. However, the safe drinking water for the surface water treatment systems should achieve less than 0.3 NTU to ensure the effectiveness of disinfection [21].

Most surface waters contain organic and inorganic particles, which most of the contained microorganisms are bad for health. Filtration used in water treatment provides the improvement of the water clarity by removing the impurity particles. Filtration also removes the contained pathogens by entangling with chemical disinfection. Filtration defined as any process removing the suspended particles from a liquid by flow the suspension through a porous medium. The filtration process that commonly used is granular filtration. Granular filtration provides a bulky bed of granular material such as sand as the porous medium and can be distinguished as rapid and slow sand filtration. The rapid filtration is 50 to 100 times faster than the slow sand filtration. In rapid filtration, granular media modified to a more identical size than which naturally found, then follow with other advanced features such as coagulation pretreatment, backwash removal, and a depth filtration [22].

The learning process to be held in this research will conduct the students to get the good reason as the basis for them to conserve the water as the natural source. They need to create a proportional relationship of the multistep ratio and percent problems based on the water filtration system that they want to build. The students also need to prove the design and give the rational reason for their project, whether it works well or not. From those descriptions, we believe that project-based learning in a STEM activity in making water purifiers can improve the creative thinking skill of the students.

2. Methods

The purpose of this research to explore the profile of student creative thinking skills under the implementation of the Project-Based Learning model of teaching. The methods are using qualitative and quantitative methods. Quantitative methods are used to analyze student achievement tests and the design of a water filtration system in solving problems related to STEM activity [34]. Qualitative methods are used to analyze data from the results of observation conducted on students to find out their creative thinking skills. The independent variable of this research is the PBL model. The dependent variable is student learning outcomes in making water purifier STEM activity. The research design uses two classes composed of control classes and experimental classes selected by purposive random sampling and examined using a pre-test and post-test using the following design.

Table 1. Design of Research using Mix Methods

Group	Pre-test	Treatment	Post-test
Control Class n=35 Student (10 males and 25 females)	O_1	-	O_2
Experiment Class n=30 Student (8 males and 22 females)	O_3	X	O_4

$\mathbf{O_1}$ & $\mathbf{O_3}$ = both groups were examined using a pre-test in order to find out their thinking skills, which was expected to be at the same level.
$\mathbf{O_2}$ = the post-test result of the control class.
$\mathbf{O_4}$ = the post-test result of experiment class

2.1 Population

In this study, the population used was fourth-semester students from the Faculty of teacher training and education at the University of Jember. Next, class selection uses cluster sampling to randomly select two classes. The total number of students in this study was 65 students, with ages ranging from 19-21 years.

2.2 Instrument

The instruments used in this study were task, observation sheets, interviews, and questionnaires. The observation of student activity sheets in both classes using a Likert scale from the interval of level 1 until 5 5 (very active), 4 (active), 3(hesitate), 2(inactive), 1(very inactive). The instrument/observation sheet was validated by the expert.

2.3 Task

In this study, students in both classes were given tasks water filtration system included in STEM activities. In the experimental class, project-based learning is applied. While in the controlled class, teaching still uses conventional methods with direct instructional methods. The application of STEM in the design of the water filtration system divided into four parts in Science, Technology, Engineering, and Mathematics. The field of science requires students understanding of acids and bases concept that related to water quality and the density concept that related to water filtration. The field of

technology requires students to find out information about how to design and develop the water filtration system. The field of engineering requires students to design an effective and efficient water filtration system. The field of mathematics requires students to carry out calculations related to the design of a water filtration system.

3. Result

3.1 Pretest Result

The teaching and learning process gives the result of implementation PBL in STEM activities in Experiment class compares with the control class that using traditional method analysis using independent sample t-test. The result of the pretest score from control and experiment class is a normal distribution, which means the class is homogenous. The total number of students in both classes is 84 students (42 student experiment class and 42 student control class). The further analysis explained by statistic software (SPSS). The result of the Pre-test scores significantly different between control class and experiment class, as seen in Table 2.

Table 2. The table display pre-test results and mean value control class and experiment class

	Class	N	Mean	Std. Deviation	Std. Error Mean
Pretest Score	Control	42	51.38	6.73162	1.03871
	Experiment	42	51.45	8.04318	1.24109

The significance value is significant to analyze and get a decision from the data display. The significant value used 5 % or 0.05. The average achievement test in the control class is 51.38, with a Standart deviation of 6.73162, and the average achievement test in the experimental class is 51.45, with a standard deviation of 8.04318. The different mean of a control class and experimental class is not significant.

Table 3. The comparison of pre-test results and mean value control class and experiment class

		Levene's Test for Equality of Variances		**t-test for Equality of Means**						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Pretest Score	Equal variances assumed	2.275	.135	-.044	82	.965	-.071	1.618	-3.29	3.14
	Equal variances not assumed			-.044	79.532	.965	-.071	1.618	-3.29	3.14

Table 3 shows the analysis of the pretest from the experimental class and control class. The result of the t-test indicates value od significant (2-tailed) 0.965 with criteria of significant value is 0.05.

According to the criteria of homogeneity, statistic means the two classes are homogenous because of the value of sig (2-tailed) bigger than 0.05.

3.2 Post-test result

The table below (Table 4.) displays a comparison of post-test results and the mean value from the control class and experiment class. Mean from control class reach 75.2619with Standart Deviation value 6.02458, while the mean of experiment class reaches 80.7143 with Standart Deviation value 5.93578. The information from Table 4 shows that there is a significant value between two classes indicated with the value of t in Levene's Test score -4.178, according to the value of $p < 0.005$.

Table 4. Comparison of Post-test result form control class and experimental class

Group Statistics					
	Class	N	Mean	Std. Deviation	Std. Error Mean
Post-test Score	1.00	42	75.26	6.02458	.92961
	2.00	42	80.71	5.93578	.91591

Table 5. The Comparison of the post-test score between experimental class and control class based on independent sample t-test.

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Post-test Score	Equal variances assumed	.169	.682	-4.178	82	.00	-5.45	1.305	-8.048	-2.85
	Equal variances not assumed			-4.178	81.982	.00	-5.45	1.305	-8.048	-2.85

Table 5. also shows the result of the independent sample t-test indicates the significant value of 0.000 ($p \leq 0.05$). Thus it is significant. The conclusion that two classes have differences in terms of student creative thinking test after implementation of RBL is STEM activity to design a water filtration system. The student activity in the experimental class observed by ten observers and related to creative thinking skills. The total result of observation student activity from the control class and experimental class shown in Figure 1 and Figure 2 below.

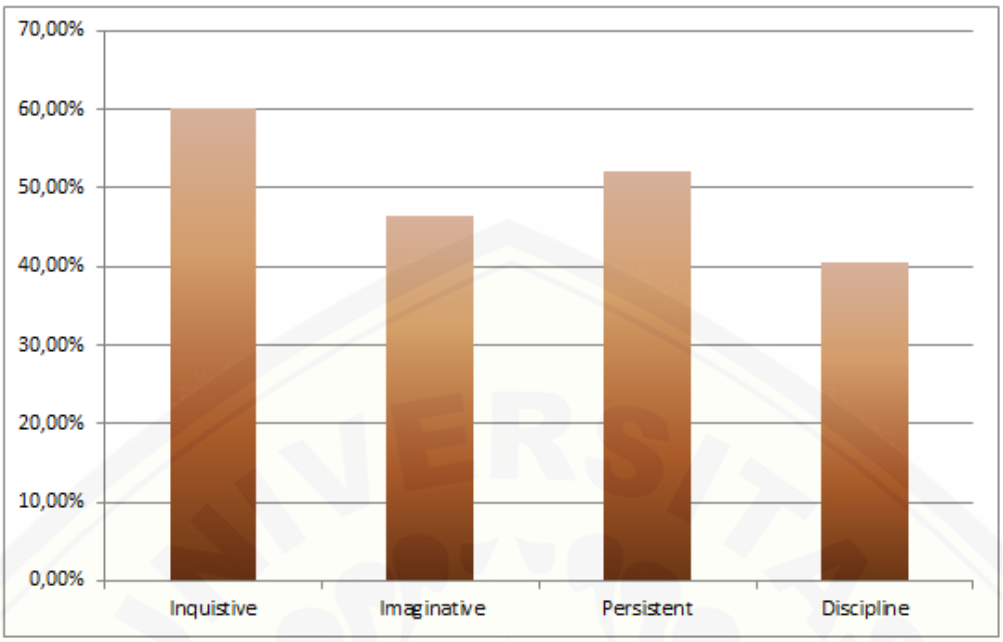


Figure 1. Student profile of Creative thinking skills in control class

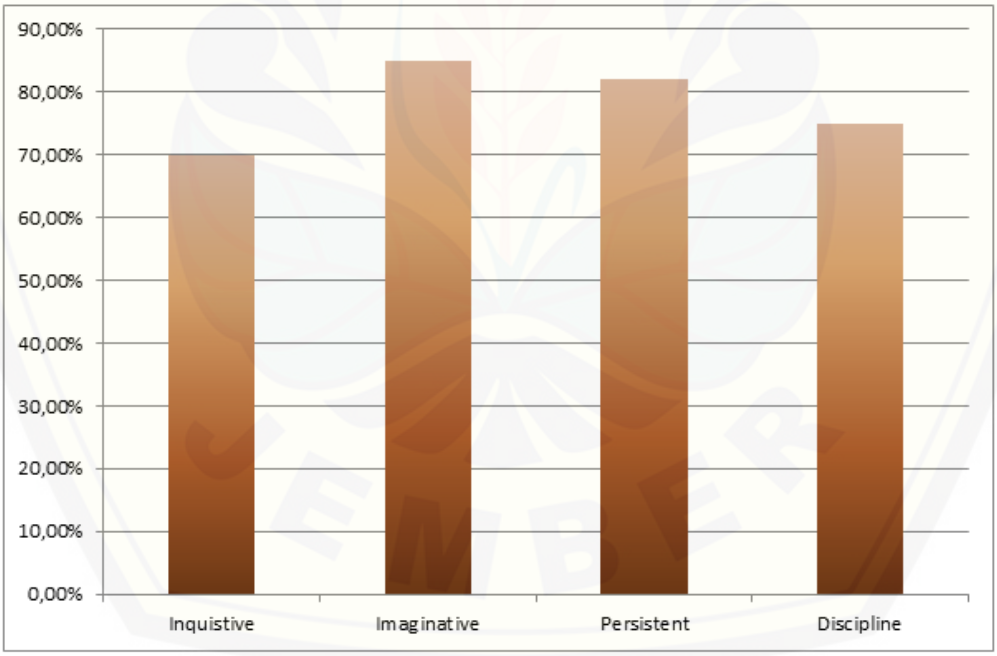


Figure 2. Student profile of Creative thinking skills in experiment class

STEM activity in water filtration system related to science concept that is the density of water, acidity, and criteria of quality water, science concept has 54% activity in STEM. The field of technology requires students to find out information about how to design and develop the water purifier. The implementation of technology has 22% in a STEM activity. The field of engineering requires students to design an effective and efficient water purifier that has 11% in a STEM activity. The field of mathematics requires students to carry out calculations related to the design of the water

filtration system has 13% in a STEM activity, the description of STEM activity in the water filtration system shown in Figure 3.

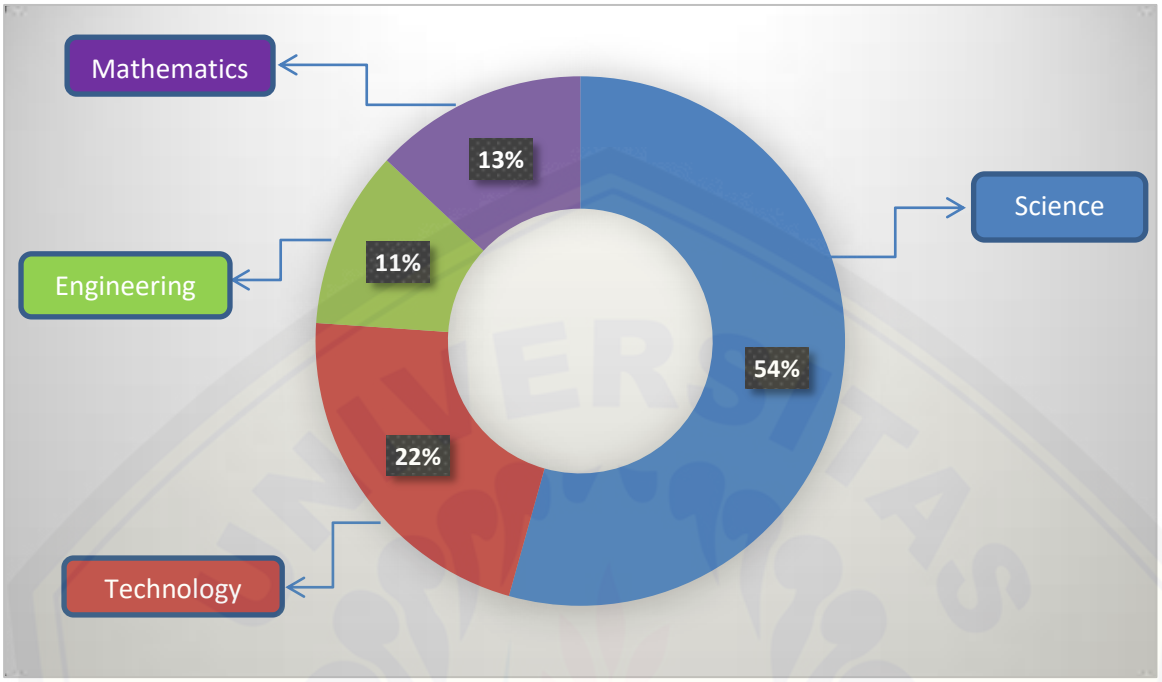
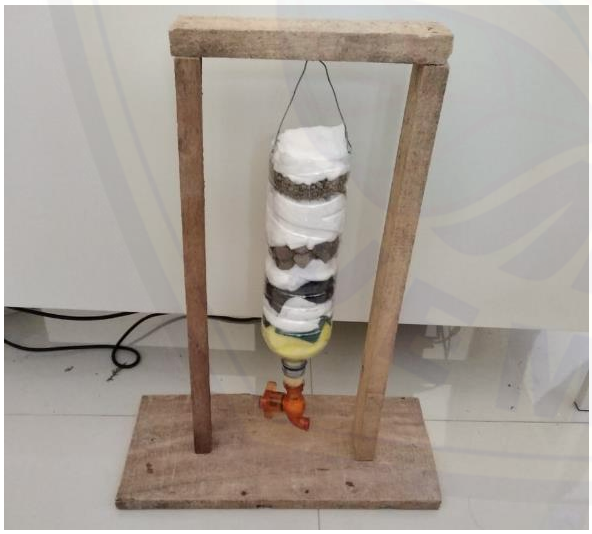


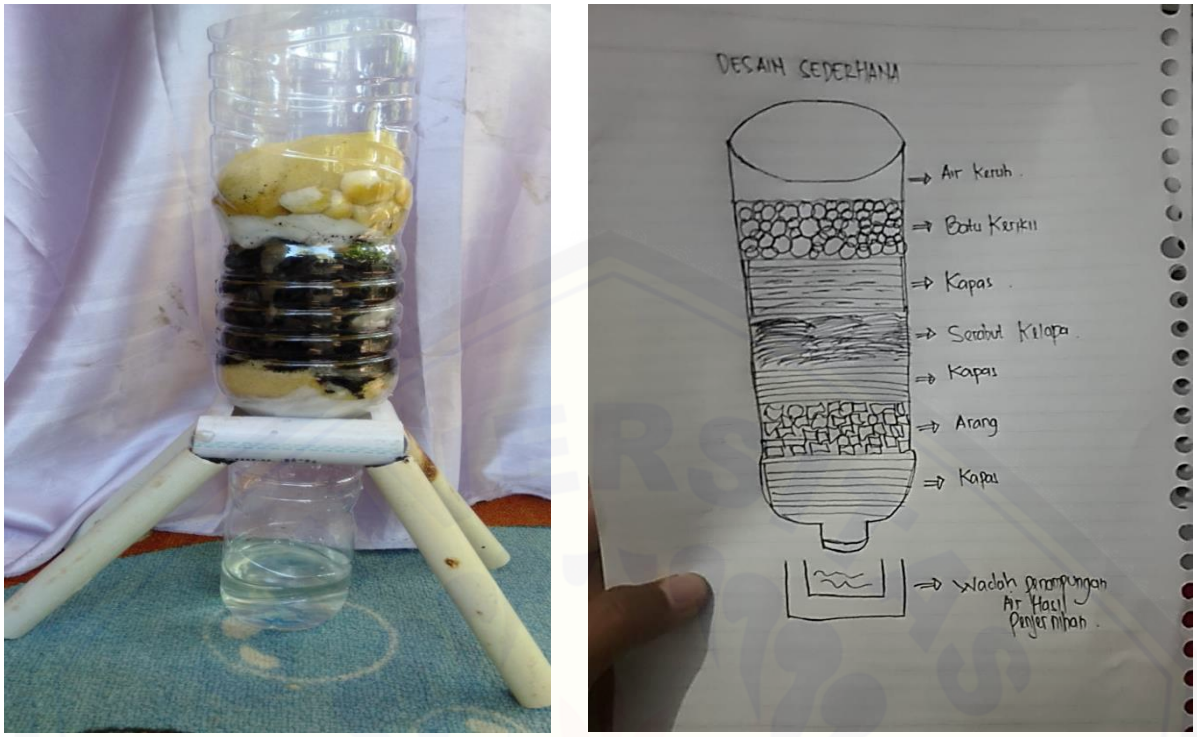
Figure 3. STEM activity in making water filtration system

The design of the water filtration system by the student under the implementation of PBL have various design



(a)

(b)



(c) (d)

Figure 4. Design of water filtration system from Student
(a) water filtration system with combination of cotton charcoal and sponge, (b) water filtration system with combination of cotton, sand, charcoal, and cotton, (c) water filtration system with combination of sponge, cotton, charcoal, zeolite, sponge and tissue, (d) design of water filtration by student

(a) **(b)**

Figure 5. The result of the water filtration system

(a) Before filtration Ph of water is 5, (b) after the filtration process, the quality of water is increase according to water quality criteria with water pH is 7.

Figure 6. The filtration procees by student

4. Discussion

The result shows that there was a difference between student creative thinking skills in two classes after implementation of RBL is STEM activity to design a water filtration system. Course taught using STEM achieves higher creative thinking skills than another class. This result is in line with previous research findings, a STEM education instructional model fostering creative thinking abilities [23]. STEM also could foster divergent thinking. [24] suggests that if teachers apply the teaching strategies, they can positively influence a student's divergent thinking, one of the important aspects of creativity. Divergent thinking is highly related to creative thinking. These skills are important in the professional and education world. Content knowledge and creative use of knowledge are needed for the student to apply their knowledge to solving problems with the different situations [25.26]. Creative thinking skill is developed for the student to face real-world careers and challenges [23]. In four aspects of the creative thinking skill that observed, only one aspect in the control class is higher than the experiment class. It is inquisitive. Other aspects such as imaginative, persistent, and discipline are higher in experimental class than control class.

Student makes different water filtration system. Their product is different for every group. It is shown that every group is thinking creatively to solve a problem about water filtration. Research has shown that creative thinking is influenced by various circumstances, including whether work is collaborative [27]. From the design, students made a water filtration system from familiar things around them. Creative thinking is related to the ability to create and make something that already exists into something new [28]. The designs are unique for every group. [29] stated that creative thinking is a form of expressing oneself in a unique way. [30] stated that classrooms in which teachers fostered student creativity show student achievement gains. Although creativity that only product-oriented is only limits creativity [31].

STEM as the classroom instruction provides instruction for students to think creatively. The teacher posts a problem about purification of water and ask students to make water filtration system. It is inline with [32] that teachers can encourage and ask students to offer multiple and varied solutions to complex problems. "E" in STEM means engineering. When engineering is approached in schools project based learning, students need to collaborate, think critically and creatively, and communicate with one another [33], that was also explained as 21st century skills.

Based on the results of this research, the researcher recommends to implement STEM especially for the science subject to solve environmental problems or others. Implementing STEM also foster students creative thinking skills. This creative thinking skill needs to be fostered because it is one of the 21st century skills. In fact, students' creative thinking skills need to be trained through learning from the early age.

5. Conclusion

The result of this research support theory and previous research that there are creative thinking skill differences. Class taught using STEM achieves higher creative thinking skills than another class. In four aspects of the creative thinking skill that observed, only one aspect in the control class is higher than the experiment class. It is inquisitive. Other aspects such as imaginative, persistent, and discipline are higher in experimental class than control class.

This research was limited to the water filtration project in undergraduate students. The research may be continued on another science project or another subject in undergraduate students. Future research also can be focused on other thinking skill, such as problem-solving skills or metacognition. The research could be focused on other skills that could be developed by STEM.

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References

[1] Moore T J, Johnson C C, Peters-Burton E E and Guzey S S 2015 The need for a STEM road map *STEM Road Map: A Framework for Integrated STEM Education* ed C C Johnson *et al* (New York: Routledge) p 374
[2] Shahali E H M, Halim L, Rasul M S, Osman K and Zulkifeli M A 2016 STEM learning through engineering design: impact on middle secondary students' interest towards stem *Eurasia J. Math. Sci. Tech. Educ.* **13** 1189–211.
[3] National Research Council 2011 *Successful STEM Education: A Workshop Summary* ed A Beatty (Washington, DC: National Academies Press) p 94
[4] Suen A and Duke S 2014 *Teaching STEM and Common Core with Mentor Texts: Collaborative Lesson Plans, K–5* (California: ABC-CLIO, LLC) p 252
[5] Banks F and Barlex D 2014 *Teaching STEM in the Secondary School: Helping Teachers Meet the Challenge* (New York: Routledge) p 287
[6] Bhandal A S 2018 *STEM - The Future of America: How to improve Science, Technology, Engineering, and Math Education in American System?* (New York: Page Publishing, Inc) p 134
[7] Duran E, Worch E, Duran L B, Burgoon J 2018 STEM in the park: a model program that provides roots for STEM learning *Natl. Soc. Sci. J.* **49** 6–12
[8] Bender W N 2012 *Project-Based Learning: Differentiating Instruction for the 21st Century* (California: Corwin) p 217
[9] Capraro R M and Slough S W 2013 *STEM Project-Based Learning: An Integrated Science, Technology, Engineering, and Mathematics (STEM) Approach* ed R M Capraro *et al* (Rotterdam: Sense Publishers) p 198
[10] Ritter S M and Mostert N 2017 Enhancement of creative thinking skills using a cognitive-based creativity training *J. Cogn. Enhanc.* **1** 243–53
[11] Zubaidah S, Fuad N M, Mahanal S and Suarsini E 2017 Improving creative thinking skills of students through differentiated science inquiry integrated with mind map *J. Turkish Scie. Educ.* **14** 77-91
[12] Montag-Smit T and Maertz CP 2017 Searching outside the box in creative problem solving: the role of creative thinking skills and domain knowledge *J. Bus. Res.* **81** 1–10

[13] Safitri D, Setiawan A, Suhandi A, Malik A, Lisdiani S A S and Sapriadil 2017 The effects of higher order thinking (hot) laboratory design in hooke law on student's creative thinking skills *J. Phys. Conf. Ser.* **1204** 1-6
[14] Hong E 2014 Creative thinking abilities: measures for various domains *Teaching and Measuring Cognitive Readiness* ed O'Neil H F *et al* (New York: Springer Science & Business Media) p 376
[15] Baer J and Kaufman J C 2012 *Being Creative Inside and Outside the Classroom: How to Boost Your Students' Creativity – And Your Own* (Rotterdam: Sense Publishers) p 163
[16] Drapeau P 2014 S*parking Student Creativity: Practical Ways to Promote Innovative Thinking and Problem Solving* (Alexandria: ASCD) p 203
[17] Stylianidou F, Glauert E, Rossis D, Compton A, Cremin T, Craft A and Havu-Nuutinen S 2018 Fostering inquiry and creativity in early years stem education: policy recommendations from the creative little scientists project *Eur. J. STEM. Educ.* **3** 1-13
[18] Dey T 2012 Magnetic nanoparticles and cellulosic nanofibers to remove arsenic and other heavy metals from water *Nanotechnology for Water Purification* ed T Dey (Boca Raton: Brown Walker Press) p 261
[19] Spellman F R and Drinan J E 2012 *The Drinking Water Handbook* (Boca Raton: CRC Press) p 374
[20] Ficai D, Ficai A and Andronescu E 2017 *Water Purification: Nanotechnology in the Agri-Food Industry* vol 4 ed A M Grumezescu (London: Academic Press) p 774
[21] World Health Organization 2011 *Guidelines for Drinking-Water Quality 4th Edition* (Geneva: World Health Organization) p 541
[22] Howe K J, Hand D W, Crittenden J C, Trussell R R and Tchobanoglous G 2012 *Principles of Water Treatment* (New Jersey: John Wiley & Sons, Inc.) p 654
[23] Chanthala C, Santiboon T and Ponkham K 2017 Affecting the activity-based on learning approaching management through the stem education instructional method for fostering the creative thinking abilities, learning achievements and environmental perceptions in physics laboratory classes of secondary students at the 10th grade level *European J. Educ. Stud*. **3** 94-122
[24] Scott D W 2004 Personality, attitude, and leader influences on divergent thinking and creativity in organizations *European J. Innov. Mgmt.* **7** 187-204
[25] Hardiman M M 2010 The creative-artistic brain *Mind, brain, and education: Neuroscience implications for the classroom* ed D A Sousa (Bloomington: Solution tree Press) pp 226-246
[26] Rotherham A J and Willingham D 2009 21st century *Educational Leadership* **67** 16-21
[27] Brophy J 2006 History of research on classroom management *Handbook of Classroom Management: Research, Practice, and Contemporary Issues* 17-43
[28] Greenstein L M 2012 *Assessing 21st Century Skills: A Guide to Evaluating Mastery and Authentic Learning* (California: Corwin Press) p 264
[29] Abraham A 2016 Gender and creativity: an overview of psychological and neuroscientific literature *Brain Imaging B* **10** 609-618
[30] Schacter J, Thum Y M and Zifkin D 2006 How much does creative teaching enhance elementary school students' achievement? *J. Crea. B.* **40** 47-72
[31] Runco M A 2003 Education for creative potential *Scandinavian J. Educ. R.* **47** 317-324
[32] Gregory E, Hardiman M, Yarmolinskaya J, Rinne L, and Limb C 2013 Building creative thinking in the classroom: from research to practice *Int. J. Educ. R.* **62** 43-50
[33] Silva E 2009 Measuring skills for 21st-century learning *Phi Delta Kappan* **90** 630-634
[34] Ridlo Z R, Dafik, Prihandini R M, Nugroho C I W and Alfarisi R 2019 *Journal of Physics: Conference Series* 1211 012049