The Influence of STEM-Based 7E Learning Cycle on Students Critical and Creative Thinking Skills in Physics

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Abstract*—Critical and creative thinking is important skills to students in the era of 21st century. This study aims to identify the effect of teaching approach called STEM-7E learning cycle on critical thinking skills and creative thinking skills. The study was carried out at two different schools in Indonesia. This study employed quantitative study using quasi experimental approach. The participants were divided into two groups which called experimental and control group. Two instrument were used in this study which were Critical Thinking Skills Test and Creative Thinking Skills Test. The Critical Thinking Test consists of three constructs which were interpretation, analysis and inference. The alpha Cronbach of critical thinking instrument is .937. The other instrument for this study is Creative Thinking Skills Test which consists of four construct; creative fluency, flexibility, originality, and elaboration. The alpha Cronbach's creative thinking skill test is .803. Both study were analysed by using mean, t-test, ANCOVA, N-gain, and effect size. As a conclusion, this study shows that the use of STEM-7E learning cycle show significance differences in increasing student critical thinking skill. On the other hand, there was significance differences between STEM-7E learning cycle and 7E learning cycle in increasing students' creative thinking.

***Keywords*—fluid statics, Temperature and Heat, critical thinking skills, creative thinking skills, STEM, 7E learning cycle**

I. INTRODUCTION

Physics is a subject that related to our daily life. For example, drinking, breathing, swimming, hydraulic lift, barometer and submarine [1]. Fluid static comprised many concepts such as density, pressure, Pascal, Buoyancy and Archimedes. In fact, learning fluid statics required good understanding in Newton's first and third law [1, 6]. Previous studies show students faced difficulties learning Fluid statics because of misconception on the concepts [9]. Such as, the students thought that fluid is the value of hydrostatic pressure depends on the area of the container [2] or the volume of the fluid inside the container [3,4,5]. Also, students has many misconception on buoyancy and hydrostatic pressure concept [7]. In Archimedes', students has difficulties in explaining the concept of submersion and buoyancy [8].

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Another topic which also difficult to students is 'Temperature and Heat' [10]. The topic of 'Temperature and Heat' covers the basic physics knowledge of keeping warm or cool. Students were reported failed to distinguish between temperature and heat [11]. Students refer heat as [1]material entity [12]. In addition, students just used formula to solve problem related to temperature and heat without understanding about the physics concept [11]. This may be due to the teachers which use one way teaching methods without involving students in active learning to discover the concepts of temperature and heat themselves [13].

II. BACKGROUND OF THE PROBLEM

Understanding of physics concepts has strong relationship with students' critical thinking [14] as well as creative thinking. Students with critical thinking are able to decide wisely and compete in global setting [15], as well as in analysing the concepts, evaluating valid evidence, and drawing conclusions in a problem [16]. However, current practices in Physics learning are limited in declarative knowledge in using a formula to solve problems [17] so that the students can only memorize without understanding the concept itself. Critical thinking involves the process of rational and reflective thinking before making a decision [18]. Critical thinking is comprised by the ability to identify faults in statements, assumptions, and information which then used to solve problems and make correct decisions [19]. Critical thinking is a process of evaluation and then deduction based on facts to make a decision [20].

On the other hand, creative thinking refers to the ability to think from various aspects of human mental operations such as smoothness, flexibility, authenticity and explain in detail the ideas of ideas developed to produce new ideas [21]. Both skills, critical and creative thinking is needed in 21st century [22] as well as a skill to be focused in education all across the nations [23]. However, 63.7% of students show low level of creative thinking skills [24]. Students demonstrated low level of critical thinking skills on concepts of hydrostatic, Pascal's Law, and Archimedes' Law [25]. According to a study [26,27,28], students show low level of creative thinking skills in Physics.

Both thinking, critical and creative thinking belongs to higher-order thinking besides problem solving, and decision-making [29]. Critical and creative thinking can be learned through intensive learning and continued practice [30]. For example, there are few studies which used teaching

and learning approaches to increase students' critical and creative thinking skills. Cognitive-Based Creativity Training has proven able to enhance students' creative thinking skills [31]. Generative learning model was shown to be able to increase students' creative thinking skills in the concept of heat transfer in topic 'Temperature and Heat' [32]. Problem-Based Learning using Macromedia Flash technology was able to improve students' creative thinking skills in the experiment of Black's principle [33]. In addition, PjBL-self regulated learning in Fluid Statics can increase critical thinking skills [17]. Discovery learning can increase students' critical thinking skills in the concept of Fluid Statics [34]. However, students still unable to think critically in making inference from the Physics problem presented using peer instruction of integrated 5E learning cycle [35].

Learning cycle (LC) is based on the theory of Piaget. It is design to help students understand the physics concept by making them actively work in solving problems [36]. A few studies stated that the utilization of surrounding environment in learning through 7E LC can increase critical thinking skills of students [37,38]. The use of 7E LC can give students a chance to construct their own knowledge in order to understand or master the concept by taking their initial understanding into account [39]. 7E LC has 7 phases [40]. 7E refers to Elicit, Engage, Explore, Explain, Elaborate, Evaluate and Extend. Elicit and Extend are two additional E in 5E LC.

STEM stands for Science, Technology, Engineering and Mathematics. Integrated STEM education refers to "an effort to combine some or all of the four disciplines of science, technology, engineering, and mathematics into one class, unit, or lesson that is based on connections between the subjects and real-world problems" (p. 38) [76]. Using STEM, students will be forced to think critically and creatively to solve problems, invent new innovation, think more logically, and become more independent [54].

III. METHOD

This study used Pre-and Post-test design in a quasi experiment setting [43]. This study involved students of grade XI in Indonesia. The respondents was 66 students from school from MAN II Batu, Indonesia and 68 students from school from SMAN I Bululawang Indonesia. They were equally distributed in the Experiment and Control group. For MAN II Batu, Indonesia they received, respectively the STEM-Based 7E LC and conventional class. While SMAN 1 Bululawang they received, respectively the STEM-Based 7E LC and 7E LC. The integration of STEM to 7E LC had been done in detail [66,67]. The difference between STEM-7E LC and 7E LC was both were carried out experiments but STEM-7E LC class produced two simple products.

Different topics were proposed to each schools. Students from SMAN 1 Bululawang Indonesia, learning topics Fluids and students from MAN II Batu, Indonesia learning topic of 'Temperature and Heat'. Fluid and 'Temperature and Heat' were two topics chosen to be studied in this study because this topics is difficult to students (4, 5, 6, 7, 8, 9, 10).

Students from MAN II Batu, Indonesia, which learning topics 'Temperature and Heat' were tested on Critical Thinking instrument. The alpha Cronbach of critical thinking instrument is .937. Students' answers were scored with rubric from "unanswered" to "correctly and completely answered" with 1, 2, 3, and 4 points. Then they were categorized into 6 criteria, which are sorted from low to high, Unreflective, Challenged, Beginning, Practicing, Advanced, and Master Thinkers [45].

Students from SMAN 1 Bululawang Indonesia, which learning topics Fluids were tested on Creative Thinking instrument. The alpha Cronbach of Creative Thinking instrument is .803. This instrument consisted of four indicators of Creative Thinking Skills, which are Fluency, Flexibility, Originality, and Elaboration. This instrument was weighted with rubric scores of 0 (unanswered), 1 (answered incorrectly), 2 (answered with 1 aspect), 3 (answered with 2 aspects) and 4 (answered with 3 or more aspects). The results were categorised into 5 levels, which are level 0 (Not Creative), level 1 (Almost Not Creative), level 2 (Quite Creative), level 3 (Creative), and level 4 (Very Creative) [44].

The data were analysed using mean, t-test, ANCOVA, N-gain, and effect size. T-test was used to know the significance difference between experiment group and control group on their score in pretest as well as in their posttest [46]. ANCOVA was conducted to know if the treatment in Experiment group improved Experiment more than Control group. The N-gain analysis was performed to classify the score could be classified into high, medium, or high category [47]. Lastly Effect size analysis of Cohen was conducted to investigate the influence of intervention towards Experiment and Control group.

IV. RESULT AND DISCUSSION

A. Critical thinking skills

The pre-test data from Experiment and Control group is written at Table 1.

TABLE I. ANALYSIS OF PRE-TEST SCORE IN EXPERIMENT AND CONTROL GROUP

Parameter	Classes	
	Experiment (n=34)	Control (n=34)
Mean (Criteria)	43.14 (Beginning Thinker)	30.39 (Challenged Thinker)
Standard Deviation	5.61	12.96

Table I shows pre-test score in experiment and Control group. The mean of the critical thinking skills score in Experiment group (43.14) is higher than the Control group (30.39). As mentioned before, there were 6 level of critical thinking, which are unreflective, challenged, beginning, practicing, advanced, and master thinkers [45]. The data shows that, Experiment group was categorised as beginner thinker and Control group was categorised as challenged thinker. This means at pre-test, students in both classes has different level of critical thinking skills. T-Test will be carried out further.

TABLE II. ANALYSIS OF T-TEST BETWEEN EXPERIMENT AND CONTROL GROUP FOR PRE-TEST

Source	Statistic Test	Sig. (2-tailed)	Alpha	Result
Between group	t-test	0.000	0.05	Differences

Table II shows analysis of T-test between experiment and Control group. There was a significance difference between Experiment and Control group at level .05. This means for pretest, students in both classes has significant different level of critical thinking skills.

TABLE III. ANALYSIS OF POST-TEST SCORE IN EXPERIMENT AND CONTROL GROUP

Parameter	Classes	
	Experiment (n=34)	Control (n=34)
Mean (Criteria)	89.22 (Master Thinker)	83.09 (Advanced Thinker)
Standard Deviation	12.40	7.25

After intervention had been done, posttest was carried out to see the differences. Table III demonstrated, the mean of the critical thinking skills score in Experiment group (89.22) is higher than the Control group (83.09). The data shows that, Experiment group was categorised as Master Thinker and Control group was categorised as Advanced Thinker. This means the level of students's critical thinking for both classes has increased after the lesson. T-test will be done for further analysis.

TABLE IV. ANALYSIS OF T-TEST BETWEEN EXPERIMENT AND CONTROL GROUP FOR POST-TEST

Source	Statistic Test	Sig.	Alpha	Result
Between group	t-test	0.013	0.05	Differences

Table IV shows analysis of T-test between experiment and Control group. There was a significance difference between Experiment and Control group at level .05. This means students in both classes has significant different level of critical thinking skills after the lesson.

Because the level of critical thinking in Experiment group (43.14) is significantly higher than the Control group (30.39) in pretest, therefore pre-test will become covariat and ANCOVA will be used for further test. ANCOVA was further conducted to know if the treatment in Experiment group (STEM-Based 7E LC) increased critical thinking skills more than the Control group (conventional). The result of ANCOVA tests is written in Table V.

TABLE V. THE RESULT OF PREQUISITE OF ANCOVA TEST

Source	Statistic Test	Sig.	Alpha	Result
Initial state-learning models Interaction	ANCOVA	0.902	0.05	No Interaction
Homogenity	Lavene's Test	0.001	0.05	No Homogenity

Table V demonstrated that was no interaction between treatment variable and initial state variable. This means that the requirements for ANCOVA test had been met. However, the homogenity test indicates that the variance of critical thinking skills Experiment group is not homogeneous with the variance in Control group. This poses no problem in ANCOVA test because the number of sample in both group are the same (n=34) [48]. Therefore, this ANCOVA test can proceed.

The result of ANCOVA test for the students' critical thinking skills in both classes if the differing initial state was controled as covariate variable is written in Table VI.

TABLE VI. THE RESULT OF ANCOVA TEST

Source	Statistic Test	Sig.	Alpha	Result
Initial state	ANCOVA	0.717	0.05	No Differences
Models	Lavene's Test	0.023	0.05	Differences

Assessment can be made from Table VI that the covariate variable of initial critical thinking skills state did not affect critical thinking skills of students in the end of learning. In other words, the initial critical thinking skills state of Experiment group which was higher than Control group did not affect critical thinking skills of students in the end of the learning process. Aside from that, Table VI also indicates that the differing treatment of both classes, which are STEM-Based 7E LC (Experiment group) and conventional approach (Control group), had caused the difference in critical thinking skills of students in the end of the research.

The average score of students' critical thinking skills in both classes after the initial state is made into covariate variable in ANCOVA statistical test can is written in Table VII.

TABLE VII. ANALYSIS OF POST-TEST SCORE AFTER PRE-TEST SCORES WERE CONTROLLED

Parameter	Classes	
	Experiment (n=34)	Control (n=34)
Mean controlled (Criteria)	89.32 (Master Thinker)	82.47 (Advanced Thinker)
Standard Error	1.915	1.915

From Table VII it's evident that the average score of critical thinking skills of students at Experiment group is higher than the Control group after the initial state is made into covariate variable in ANCOVA statistical test. This "adjusted" result in Table VII is almost the same with the "unadjusted" result (in which the differing initial state wasn't made into covariate variable) in Table III. Also, the Experiment group had the level of critical thinking skills in Master Thinker, which is higher than Control group in Advanced Thinker by one level. This results indicated that STEM-Based 7E LC learning affects the gain in students' critical thinking skills.

The STEM-Based 7E LC learning is better than conventional approach in enhancing the critical thinking skills of students. The results of this study are supported with the findings of some other research. Physics STEM Education Learning is able to produce better score of CTS than the conventional class [49]. The application of 7E LC

model is more effective in enhancing the critical thinking skills of students than the application of conventional approach [50]. The critical thinking skills of students with 7E LC model is higher than the conventional model [51]. Students' critical thinking skills with 7E LC is better than students' critical thinking skills with conventional model [52].

In the Experiment group, two cycles of STEM-Based 7E LC were conducted. In the first cycle, the students produced a small-scale hydraulic lift as the product of learning process, whereas the second cycle produced a small-scale submarine. The first product was the result of the application of Pascal's Law, whereas the second product was the result of the application of theory of Buoyancy and Archimedes' Law. However, both Pascal's and Archimedes' Law require good initial understanding of Newton's First and Third Law. This product oriented process was able to make students more active to communicate their understanding of relevant concepts through STEM education [53]. If the students are active during learning, their scientific reasoning can also be put to exercise in developing critical thinking ability [54].

In learning, generally, the concepts are taught separately. However, in STEM principle, students can apply those concepts in daily practices based on their relevant experiences. This way, students can feel more motivated to learn about the knowledge more [55]. The emphasis on the aspects of STEM in learning has a chance to improve individual's 21st century skills, namely critical thinking, creativity, curiosity, and collaboration) [56]. Also, learning with STEM in reality can practice students to capable to communicate, think critically, collaborate, and solve problems, as well as to be more creative and innovative so that they'll be more prepared to tackle the challenges in these modern times [57]. Last but not least, the integration of learning process with STEM can further encourage students to pursue their interests, job aspirations, and curiosities in the world of science and mathematics [58].

From the data of pre- and post-test score, the critical thinking skills can be quantified with N-gain as is written in Table VIII.

TABLE VIII. N-GAIN RESULT OF CTS IN EXPERIMENT AND CONTROL GROUP

Parameter	Classes	
	Experiment (n=34)	Control (n=34)
N-gain Class (Category)	0.810 (High)	0.757 (High)

Table VIII shows that the N-gain of Experiment group is higher than the Control group. The result shows that STEM-Based 7E LC is more effective in increasing critical thinking skills or students than conventional approach. The standing of rank of the two classes is the same with the rank based on ANCOVA analysis where the proposed learning method sits atop. The N-gain scores of Experiment and Control group belong in the equal "high" categorization. The N-gain in Experiment and Control group had far surpassed the threshold of the N-gain average of active students learning in the commonly acknowledged score of 0.48 [59].

This study covers 3 indicators in critical thinking skills test instruments, which are Interpretation, Analysis, and Interfere. The indicators and their respective N-gain scores is written in Table IX.

TABLE IX. N-GAIN SCORE OF INDICATORS OF BOTH CLASSES' CTS

Indicators	N-gain Classes (category)	
	Experiment (n=34)	Control (n=34)
Interpretation	0.784 (High)	0.784 (High)
Analysis	0.805 (High)	0.737 (High)
Interfere	0.840 (High)	0.750 (High)

From Table IX, it can be seen that students were successful in improving their critical thinking skills score in each indicators. In fact, the Experiment and Control group all have high category in their gain. In the Interpretation indicator, students in both class has equal N-gain. This indicates that the students in both classes has the same ability in categorizing, significantly decoding, and meaning clarification. In the Analysis indicator, the N-gain score of Experiment group is better than Control group. This indicates that students in Experiment group has better ability to give ideas, identify the reasoning, and formulate statements than the Control group. In the Interfere indicator, N-gain of students in Experiment group is higher than Control group. This indicates that the students in Experiment group had much better ability than Control group in searching evidence, making alternative deduction, and making valid or logical conclusion. The difference in these two indicators was the result of Engineering activities in Experiment group, which produced two products by the end of the learning process (a small-scale hydraulic lift and submarine based on the Pascal's Law and Archimedes' Law). The presence of these products in learning can improve the long term retention of information in students [60].

Analysis of the effect size of the critical thinking skills or students' in both classes was conducted. The value is written in Table X.

TABLE X. EFFECT SIZE ANALYSIS IN EXPERIMENT AND CONTROL GROUP

Parameter	Experiment and Control group Pair
d effect size	0.603
Category	Medium

From Table X, it's apparent that Experiment and Control group pairing's effect size belongs in "medium" categorization. Such result indicates that STEM-Based 7E LC implementation has the impact or influence in medium category relative to conventional approach, specifically on the CTS increase amongst the students.

The result of students' response towards the learning acivity is presented in Table XI.

TABLE XI. THE "AGREE" (A) AND "STRONGLY AGREE" (SA) RESPONSE IN EXPERIMENT AND CONTROL GROUP

Classes	Students' response (%)		Total (%)
	A (agree)	SA (strongly agree)	
Experiment group (N=34)	65.30	29.44	94.74
Control group (N=34)	64.08	19.59	83.67

From Table XI it's evident that both Experiment and Control group have positive response towards the learning activity, which can be seen by more than 50% students stated A and SA in the questionnaire. However, it can be seen that the Experiment group has better response than the Control group. Also, the SA response in Experiment group was higher than Control group. Such result implicates that STEM-Based 7E LC learning was felt more comfortably by students than the conventional learning. This result is consistent with the finding that Physics STEM Education Learning can produce higher satisfaction than conventional method [61].

B. Creative thinking skills

TABLE XII. ANALYSIS OF PRE-TEST SCORE IN EXPERIMENT AND CONTROL GROUP

Parameter	Classes	
	Experiment (n=34)	Control (n=34)
Mean (Criteria)	28.50 (Almost Not Creative	24.17 (Almost Not Creative
Standard Deviation	9.48	9.78

The results show both classes had similar level of creative thinking skills. The pre-test data satisfied the normality and homogeneous assumptions. Independent-sample t-test was carried out to identify significance differences of the level of critical thinking skills before lesson. Table XIII presents the result of this analysis.

TABLE XIII. ANALYSIS OF T-TEST BETWEEN EXPERIMENT AND CONTROL GROUP FOR PRE-TEST

Source	Statistic Test	Sig. (2-tailed)	Alpha	Result
Between group	t-test	0.076	0.05	No Differences

Table XIII shows analysis of T-test between experiment and Control group. There was no significance difference between Experiment and Control group at level .05. This means students in both classes has no significant different level of creative thinking skills.

TABLE XIV. ANALYSIS OF POST-TEST SCORE IN EXPERIMENT AND CONTROL GROUP

Parameter	Classes	
	Experiment (n=34)	Control (n=34)
Mean (Criteria)	74.50 (Creative)	64.32 (Creative)
Standard Deviation	6.99	8.19

Table XIV shows pre-test score in experiment and Control group. The mean of the creative thinking skills score in Experiment group (74.50) is higher than the Control group (64.32). As mentioned before, there were 5 levels of creative thinking skills, which are level 0 (Not Creative), level 1 (Almost Not Creative), level 2 (Quite Creative), level 3 (Creative), and level 4 (Very Creative) [44]. The data shows that, Experiment group was categorised as Creative as well as Control group. This means the level of students' creative thinking skills for both classes has increased after the lesson. As the post-test data satisfied the normality and homogeneous assumptions, t-test analysis was conducted.

TABLE XV. ANALYSIS OF T-TEST BETWEEN EXPERIMENT AND CONTROL GROUP FOR POST-TEST

Source	Statistic Test	Sig. (2-tailed)	Alpha	Result
Between group	t-test	0.000	0.05	Differences

Table XV shows analysis of T-test between experiment and Control group. There was significance difference between Experiment and Control group at level .05. This means students in both classes has significant different level of creative thinking skills. The data shows, STEM-7E LC class had achieved significantly higher level of creative thinking skill compared to Control group in topic of Temperature and Heat.

During the intervention, both groups worked on four experiments and they are required to present the results in class. However, for STEM-7E LC group, they are required to produced two products, which were fire alarm and air conditioner. Several activities were conducted such as tested the product, designed design, presentation and report writing. Students in Experiment group worked more than Control group. By using STEM 7E LC, the students communicate about the concepts with their group member [62]. By using STEM 7E LC, students were required to apply many concepts in order to solve the problem. This encourages students on their learning [63]. The integration of STEM in 7E LC able to motivate the students' interests, career interest, and their aspirations in science and mathematics [64]. Therefore, STEM-7E LC group can improve students' creative thinking skills better than Control group in the topic of Temperature and Heat. The result of this study is similar with the previous study on Equilibrium topic [65]. The study shows STEM intervention successfully increase students' creative thinking skills in grade X in the topic of Equilibrium [65]. There were also students' worksheet with STEM approach which results in increasing students' creative thinking skills [66]. Lastly, STEM learning was proven to be able to enhance students' creativity through the process of problem solving in everyday life [67].

By using STEM 7E LC, the level of creative thinking skills of experimental groups were increase "Almost Not Creative" at pretest to "Creative" at posttest. This is also similar to Control group which used 7E LC whereas the students' level of creative thinking also increased from "Almost Not Creative" at pretest to "Creative" at posttest. The level of Creative thinking of both groups successfully

increase because both STEM-7E LC and 7E LC group were not similar to conventional class. Generally, in conventional class, when students were given an essay physics problem (without mathematical hints) and in a form of story, students tend to answer by constructing physics concept through mathematical equations than to elaborate using relevant concepts [69].

The N-gain analysis of pre-test and post-test data resulted in 0.643 (medium) for Experiment group, and 0.529 (medium) for Control group. This results show that the STEM-Integrated 7E LC used in Experiment group was able to increase students' creative thinking skills higher than 7E LC learning in Control group. This finding is consistent with the t-test result in post-test data above. Based on previous research, there was a threshold of N-gain mean at the score of 0.48 in learnings which involve active students [34]. The N-gain analysis in this research shows that the Experiment group acquired N-gain score way above the threshold. This is in accordance to a study about the successful use of STEM to increase students' creative thinking skills [65]. However, the Control group was also able to acquire an N-gain score slightly above the threshold. This is because the Control group was not, by any means, a conventional class. This is also in line with the findings that 7E LC can improve students' creative thinking skills [70].

The result of N-gain analysis of 4 creative thinking skills indicators can be seen in Table XVI.

TABLE XVI. N-GAIN SCORE OF CREATIVE THINKING SKILLS IN EACH INDICATOR

Indicators	N-gain Classes (category)	
	Experiment (N = 30)	Control (N = 36)
Fluency	0.712 (High)	0.604 (Medium)
Flexibility	0.680 (Medium)	0.431 (Medium)
Originality	0.667 (Medium)	0.505 (Medium)
Elaboration	0.590 (Medium)	0.504 (Medium)

From Table XVI, it can be seen that all indicators in Experiment group has higher N-gain score than Control group. Both classes acquired highest N-gain score in Fluency indicator. Apparently, students in both classes was able to develop Fluency creative thinking skills indicator by providing various relevant answers to the questions of heat transfer in real world examples. However, in this indicator, the Experiment group acquired the N-gain in high category while the Control group acquired Medium category in N-gain score. This is due to the more active involvement of students in Experiment group while making and testing an engineering product of simple air conditioner. Also, in the Flexibility and Originality indicators, students in Experiment group acquired higher N-gain category than Control group. This is caused by the learning in the Experiment group where students endeavored to make an engineering product of simple fire alarm. Students which think creatively can create ideas and solutions of a problem so that they can construct previously non-existent products and then produce valuable and worthy invention [71].

For Elaboration indicator, students in both classes had the lowest N-gain score. Students had not yet optimally flesh out the details of their ideas to be defined more clearly. This finding is similar with the study which stated students' elaboration still belonged in Quite Creative category [70]. Perhaps, students are still having misconceptions about the relation between Temperature and Heat. Students still think that objects with big mass also have high temperature while objects with small mass have low temperature in the subtopic of Heat [72]. Also, students stated that different objects will have different temperature if left in a same environment in a long time [73]

Cohen's effect size analysis of students' creative thinking skills in Experiment-Control group pair resulted in d = 1.33 "Very Large" category. This implies that the operationalizing implementation of STEM-7E LC had the impact in "Very Large" category compared with 7E LC in regards to the improvement of students' creative thinking skills. In real world practice, STEM-7E LC can be widely implemented in order to increase students' creative thinking skills. Creative thinking skills is a natural ability which is needed and maintained so that creative individual can help the society solve different problems in daily lives [74].

The result of students' response in questionnaire towards the learnings showed that Experiment group had better response than Control group, with respective percentage of 91.29% and 87.71% for the "Agree" and "Strongly Agree" answer. However, these results are almost similar. This indicates that students were very comfortable in the learning environment of either STEM-7E LC or 7E LC. This is due to the fact that both STEM-7E LC and 7E LC classes were not conventional classes. This is consistent with the finding that Physics STEM Education Learning class was able to give more comfort towards students than conventional class [76]. can help the society solve different problems in daily lives [73].

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V. CONCLUSION

As a conclusion, this study shows that the use of STEM-7E LC show significance differences in increasing student critical thinking skill compared to conventional class. The level of Experimental group at pretest is at Beginning Thinker (43.14) and increased significantly to Master Thinker (89.22) level after posttest. While for control group, the level of critical thinking skills increased significantly from Challenged Thinker (30.39) at pretest to Advanced Thinker (83.09) at posttest.

On the other hand, there was significance differences between STEM-7E learning cycle and 7E learning cycle in

increasing students' creative thinking. Both groups increased their creative thinking skills from Almost Not Creative to Creative levels. The increase of creative thinking skills in both group was at medium category except for fluency. However, the result from each indicator showed that Experiment group had higher N-gain score than Control group. Furthermore, the Experiment group had high category in Fluency indicator. The operasionalization of STEM-7E LC, which had d = 1.33 in a "Very Large" category, showed that it had more impact than 7E LC in increasing students' creative thinking skills.

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