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Improving Creative Thinking Skill of Fluid Dynamic through IBL-STEM with Formative Assessment

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Abstract. The concept of Dynamic Fluid is part of the Fluid Mechanics that underlies several phenomena and technologies in everyday life. Improving students' ability to think creatively is needed to prepare students for the challenges of the 21st Century. However, students' creative thinking skill are still low on dynamic fluid material, and the application of integrated STEM Inquiry with Formative Assessment (IBL-STEM with FA) solutions is still rare. This study aims to improve students' creative thinking skill and describe the difficulties of creative thinking on Dynamic Fluid material after IBL-STEM with FA. The mixed methods with an embedded experimental design used the research subjects of 34 students (M = 14 and F = 20) in class XI of state senior high schools in Jombang, Indonesia, selected by purposive sampling. This study used the Fluid Dynamics Creative Thinking Skill Test instrument in the form of 6 essay questions with a reliability of 0.869. The pretest and posttest quantitative data were analyzed by the Wilcoxon test, d effect, and N-gain. Whereas qualitative data on the variety of students' answers, and the results of interviews and observations were analyzed by coding, data reduction, and conclusion gathering. Variety of student answers was coded based on not creative, less creative, quite creative, creative, and very creative. The results showed that intervention significantly increased students' ability to think creatively with N-gain = 0.64 (medium category) and d-effect size = 5.05 (very large category). After learning, students were still experiencing difficulties to think flexibly both (1) developing tools based on continuity concept and (2) developing an effective and environmentally friendly chimney design. Also, students still have difficulty in original thinking to get high speed and widespread sprayers. Nevertheless, an increase in students' creative thinking on dynamic fluid material indicates that IBL-STEM with FA can be applied in learning.

BACKGROUND

Dynamic fluid is one of the materials in physics whose application is often found in everyday life. This concept is used as the basis for several phenomena and technologies such as fountains, aircraft lifting forces, hydram pumps and others. However, students still find it difficult to learn the concept of dynamic fluids. Students find it difficult to understand dynamic fluids because there are significant differences with solid matter mechanics (1,2), they find it difficult to understand the ratio between velocity of fluid flow and pressure (3), and students find it difficult to determine solutions to problems related to dynamic fluids in everyday life (4,5).

The concept of dynamic fluids related to the demands of the 21st century refers to students' creative thinking skill. On the other hand, creative thinking must be supported by strong conceptual mastery skill of a material (6,7). However, students' creative thinking skills are still low. Based on the PISA results, the scores of several countries are still below the average, including Indonesia (8,9). In fact, this ability has begun to be needed in all areas of life, including science. Therefore, learning that focuses on increasing creative thinking skills is needed (10,11).

Students' creative thinking skills can be improved through the selection of active learning (6,7). Several learning strategies have been implemented to improve students' creative thinking skills, including Model Project Creative Learning (PCL) (12), Problem based instruction (13), Mind map (14) and ERCoRe learning (11). However, there are

difficulties faced, among others, it takes a long time to increase the creative thinking component (12) and only the fluency and elaboration components increase (9,15). On the other hand, several recommendations state that the use of inquiry based learning can improve students' creative thinking skills (16–18).

Inquiry based Learning (IBL) makes students become like researchers. Students are given the freedom to identify problems, design experiments, and present the results of the experiment (18–20). IBL also gives students freedom in developing their ideas (16,21). With this freedom, students' creative thinking skills can increase (17). However, other studies suggest that students are not attracted to IBL because the set of experiments does not correspond to real life (22). On the other hand, this study recommends the integration of STEM in IBL (23,24).

The combination of IBL and STEM completes the role of students as the main actors in learning. In addition to students as researchers, the STEM approach places students as engineers (24–26). Integration of scientific fields in STEM (science, technology, engineer, mathematics) will increase knowledge and skills comprehensively to improve students' creative thinking skill (24,27). However, it takes a long time to get students used to the STEM learning pattern (5,28,29). Therefore, researchers combined IBL-STEM with formative assessment (FA) to help students achieve learning goals effectively. Formative assessment (FA) is a form of assessment for learning. Through the components of the FA (sharing learning expectation, questioning, feedback, self-assessment, and peer assessment), students are helped in achieving learning goals (30,31). The results of the questioning, feedback, self assessment, and peer assessment are used as the basis for the teacher in determining the form of learning (31,32).

The combination of IBL-STEM with FA is proposed as a learning solution to improve students' creative thinking skills. The constituent elements of this combination are in accordance with the characteristics of the ability to think creatively. So that the purpose of this study is to improve student's creative thinking skill and describe the difficulties of students with dynamic fluid material after IBL-STEM with FA.

METHOD

This study uses a mixed method as a research methodology. The research design used was an embedded experimental pre-posttest model (33). The research subjects were 34 students of class XI IPA (M = 14; F = 20) in Jombang Regency. The research subjects were determined through purposive sampling (33). The research begins with a pretest to determine students' initial creative thinking skills. The research treatment was in the form of Inquiry Based Learning (IBL) Learning Model(20) integrated STEM (1) with *Formative Assessment* (30)(IBL-STEM with FA) to improve students' creative thinking. The Orientation syntax is combined with the Science Technology component and the Sharing Learning expectation and Questioning components to train fluency and elaboration. Syntax Conceptualization (Questioning, and Hypothesis Generation) is combined with the Science component and the Questioning and Feedback component to train fluency and originality. Syntax Investigation (Experimentation, and Data Interpretation) is combined with the Science and Mathematics component and the Questioning and Feedback component to train Fluency; Flexibility; Originality; Elaboration. Syntax Conclusion is combined with aspects of Science, Engineering, and Mathematics and components of Self Assessment, and Peer assessment to practice originality and elaboration. Syntax Discussion (Communication, and Reflection) is combined with aspects of Science, Engineering, and Mathematics and components of Self Assessment, and Peer assessment to train flexibility and originality.

Collecting research data using Fluid Dynamic Creative Thinking Skill Instrument in the form of 6 essay with reliability 0.869. The questions consist of 6 questions covering creative thinking components, namely fluency, flexibility, originality, and elaboration (34–36). The data analysis method used inferential statistical analysis in the form of the Wilcoxon test to determine differences in students' creative thinking skill before and after treatment. (37), N-gain test to determine the increase in students' Creative Thinking Ability (12,37), and d-effect to measure the effectiveness of the treatment (37). In addition, qualitative data in the form of students' answers, interview results, and observations were analyzed by means of coding, data reduction, and conclusions gathering. (33). The student's answers were coded based on the creative thinking rubric adapted from Hu & Adey (38) and Treffinger in Zubaidah, Fuad, Mahanal, Suarsini (39). The following is a table of students' Creative Thinking Ability coding.

TABLE 1. Table of student creative thinking coding

Indicators	Category	Level	Criteria
Fluency	Not Creative	0	No answer or incorrect answer
	Less Creative	1	Mentioning/writing down one idea, suggestion or alternative answer
	Quite Creative	2	Mentioning/writing down some ideas, suggestions or alternative answers that are not too different

The Continuation of Table 1

Indicators	Category	Level	Criteria
<i>Fluency</i>	Creative	3	Mentioning/writing down three different ideas, suggestions or alternative answers
	Very Creative	4	Mentioning/writing down four or more different ideas, suggestions or alternative answers
<i>Flexibility</i>	Not Creative	0	No answer or incorrect answer
	Less Creative	1	Writing down one alternative answer that is quite logical and relevant to the given problem from only one perspective
	Quite Creative	2	Writing down some alternative answers that are quite logical but not relevant to the given problem from various perspectives
	Creative	3	Writing down some alternative answers that are quite logical and relevant to the given problem from various perspectives
	Very Creative	4	Writing down some alternative answers that are very logical and relevant to the given problem from various perspectives
<i>Originality</i>	Not Creative	0	No answer or incorrect answer
	Less Creative	1	Mentioning/writing down ideas that are common, logical and relevant to the given problem. The answer frequency is more than 15% (> 5) of the total students in one class
	Quite Creative	2	Mentioning/writing ideas that are quite unique, interesting, logical and relevant to the given problem. The answer frequency is between 11%-15% (4-5) of the total students in one class
	Creative	3	Mentioning/writing down some unique ideas that are logically interesting, relatively new but less relevant to the given problem. The answer frequency is between 5%-10% (2-3) of the total students in one class
	Very Creative	4	Mentioning/writing some unique ideas that are interesting and logical, relatively new and relevant to the given problem. The answer frequency is less than <5% (2) of the total students in one class
<i>Elaboration</i>	Not Creative	0	No answer or incorrect answer
	Less Creative	1	Not adding details to existing ideas so that the idea formulation is less applicable
	Quite Creative	2	Giving some logical details of an idea that already exists but is not following the concept of the idea so that it cannot be used to clarify the idea
	Creative	3	Explaining one logical detail of an existing idea so that the idea formulation is easier to apply and clear
	Very Creative	4	Explaining some logical details of an existing idea so that the idea formulation is easier to apply and clear

RESULTS AND DISCUSSION

The research data were tested for normality and homogeneity. The one sample Kolmogorov-Smirnov test shows the data is normally distributed with a significant value of more than 0.05. Meanwhile, the Test of Homogeneity of Variances shows that the data is not homogeneous with a significant value less than 0.05. Based on the prerequisite test results, the research data was tested using the Wilcoxon test. The significant value with the Wilcoxon test is less than 0.05 so that there are significant differences before and after the IBL-STEM with FA treatment on students' creative thinking skill. The research data analysis was strengthened by the N-Gain value of 0.64, which means that the increase in students' creative thinking skills was in the medium category. The d-effect size value is 5.05 (very large category), which means that the IBL-STEM with FA treatment is very effective in improving students' creative thinking skills.

This study aims to improve students' creative thinking skills. The treatment given is in the form of implementing the STEM integrated Inquiry Based Learning learning model accompanied by Formative Assessment (IBL-STEM with FA). Students' creative thinking skill are measured on Dynamic Fluid materials including fluency, flexibility, originality, and elaboration (9,11). The discussion focuses on the formulation of IBL-STEM with FA in improving students' creative thinking skills and difficulties faced after treatment.

The combination of the IBL-STEM with FA learning model can improve students' creative thinking skills of dynamic fluid. This is supported by the results of research that inquiry-based learning can improve students' creative thinking skills (16–18) and use them in solving problems based on their own ideas (21). In addition, the STEM

approach has been proven to facilitate the improvement of students' creative thinking skills (24). This combination is also strengthened by formative assessment as a medium and confirmatory for students to achieve learning objectives (30,31).

Inquiry-based learning (IBL) places students as researchers. Students are free to develop ideas to design their own investigations (20,40). This freedom then increases students' creative thinking skills to solve problems based on the results of the investigation (16,19). The results of other studies indicate that the cognitive structure of students improves when given the opportunity to acquire their own knowledge (41). This increase in cognitive structures spurs creative thinking skill (fluency, flexibility, originality, and elaboration) to develop optimally (9,11,15). So, it can be concluded that IBL can improve students' creative thinking skill (17,18).

The STEM approach places students as engineers. The integration of STEM in IBL gives students the opportunity to apply their new knowledge in solving contextual problems. Students' creative thinking skill (fluency, flexibility, originality, and elaboration) increase as they solve problems of expensive water jets and scarcity of water in the highlands. This is supported by the results of research that the use of STEM can improve students' creative thinking skills (24,27). Formative Assessment (FA) as an assessment for learning effectively. Through its constituent components, teachers can provide feedback to students from answers to questions, self-assessments, and peer assessments (30,31). From this feedback, students feel confident and more open to expressing all their ideas and thoughts (42,43). Openness triggers an increase in students' creative thinking skills both to solve problems or develop prototypes (17).

Some students' difficulties in thinking creatively were found after the IBL-STEM with FA learning. These difficulties were identified based on the percentage of students with the "Quite Creative" category of more than 20%. First, Students find it difficult to think flexibly to develop tools based on the principle of continuity. The pretest results showed 23% were not creative, 14.71% were less creative, and 61.76% were quite creative. After the intervention, as much as 2.94% were less creative; 23.53% quite creative; 20.59% creative; and 52.94% are very creative. As many as 8 students found it difficult to mention the development of tools from the concept of the Principle of Continuity. Table 1 shows the descriptions of students' answers on the flexibility component.

TABLE 2. Recapitulation of student answers on the flexibility creative thinking skill

Indicator	Student Answer	Category
Presented the conclusion of the experiment on the principle of continuity, students can provide a variety of ideas about tools that apply the principle of continuity	Watering hose for plants	Less
	Fire hose	Creative
	Watering hose for plants	Quite
	Fire hose	Creative
	Pest sprinklers used by farmers	
	Watering hose that can be changed in cross-sectional area manually or with a tool that can be purchased at the store	Creative
	Fire hose which has a cross-sectional area controller	
	A fountain whose cross-sectional area can be changed according to the Principle of Continuity	
	Watering hose can change automatically, so it can be used without human labor	Very
	Fire officer hose whose cross-sectional area can be changed according to the arrangement to reach the point of fire	Creative
	The meat cutter uses the water jet principle	
	Fountains that can be changed the surface area of the hose so that the range of the shower can change and look like dancing	
	Making a spray room for washing cars, can be combined with the Pascal legal system to lift the car so that when washing a car, it does not need human labor	
	Air-spraying dust cleaners can be used to clean confined spaces such as carburetors for vehicles	

Table 2 shows a recapitulation of students' answers in developing tools based on the principle of continuity (flexibility). Students in the quite creative category only focus on plant sprinklers, fire hose, and plant sprinklers. According to the flexibility indicator, the 8 students only looked at the development of tools based on the principle of continuity from a little perspective, namely the perspective of the water hose (11). This is because students are still fixated on simple thoughts observed from everyday life. Students are still at the contextual observation stage and have not progressed towards the development stage (1,4,44). Students only think about the relationship of cross-sectional area which is inversely proportional to flow velocity only.

Second, students find it difficult to think flexibly in designing an effective and environmentally friendly chimney. The pretest results showed that 38.24% were not creative, 14.71% were less creative, 17.65% were quite creative, and 29.41% were creative. After learning IBL-STEM with FA, as many as 8.82% were less creative, 79.41% were quite creative; 5.88% Creative; and 5.88% Very Creative. A total of 27 students found it difficult to think and think flexibly in determining an effective and environmentally friendly factory ceiling design. Table 3 shows a description of the students' answers to the flexibility component.

TABLE 3. Recapitulation of students' answers on the flexibility creative thinking skill

Indicator	Student Answer	Category	
Presented the problem of pollution in the chimney, students can think flexibly to get an effective and environmentally friendly factory design	Build a high chimney pipe	Less	
	Build factories that are far from residential areas	Creative	
	Build an environmentally friendly factory		
	Using environmentally friendly materials	Quite Creative	
	Added a fan on the exhaust engine to push the smoke out of the chimney		
	The chimneys are made in a cone shape according to the Bernuolli principle so that smoke rises to the top so that it does not pollute the environment		
	Use a smoke booster to let the smoke escape into a high chimney		
	The chimney is made high so that smoke does not pollute the environment	Creative	
	Replace the chimney pipe periodically so as not to add pollutants		
	Make a high chimney pipe so that it does not interfere with the surrounding environment		
	The chimney pipe above is connected to the wind so that the pressure is low so that the smoke can go up		
	Using anti-pollutant tools		
	Make a pipe chimney equipped with an air filter so that the air that comes out is cleaner		Very Creative
	Create exhaust rooms where each room has a gas filter		
	Adding a fan at the top of the chimney so that the smoke that comes out does not pollute the environment around the factory		Creative
	Adding pressure at the base of the chimney to allow the smoke to go to a low pressure area above the chimney		
Make a closed room as a factory exhaust and connect it with a chimney connected to the wind			

Based on table 3, Students in the Quite creative category only answered with a number of less than 3 answers, the answer logic was low, and the relevance was also low (11). Students think it is necessary to add a booster or fan to push the factory smoke into the exhaust pipe. In addition, making high chimneys will reduce environmental pollution around the factory. Students also think that a cone-shaped chimney can make the smoke flow up the chimney effectively. In terms of the ability to think creatively, students have the courage to put forward ideas based on the problems given, even though the students' answers are less relevant to the concept of law. This is because students find it difficult to connect concepts to real life (1,44,45). Basically, the basis of the ability to think creatively is mastery of good concepts (6,7,46).

Difficulty in flexible thinking (flexibility) greatly affects students' creative thinking skill. Flexibility represents the diversity of ideas from an individual (6,47). In addition, Flexibility also requires more than one mastery of knowledge (48,49). Students must use a variety of perspectives in issuing ideas or ideas (11,48). Therefore, to train flexibility, learning must focus on the role of students as learning subjects (6,7,14)

Third, students find it difficult to think in original terms to get high and wide speed on the mosquito spray. The pretest results showed that 67.65% were not creative and 32.35 were less creative. After the posttest, as many as 91.8% of students were categorized as quite creative and 8.82% were categorized as creative. A total of 31 students found it difficult to think in original terms to determine how to get high speed and spread to the sprayer. Table 4 shows the descriptions of students' answers to the originality components.

Students assume that increasing the speed of the spray can be done by increasing the pressure and pushing force of the T tube, the hole in part A is made flattened, reduces the area A, makes an oval of area B, fills the tube where the liquid is B, and increases the length of the tube T. actually already understand the basis of Bernoulli's Law. The student's answer leads to narrowing one of the holes to get a high velocity in hole A. After that, the difference in speed results in a difference in strength in part B so that the water can be lifted. As many as 91.18% of students answered with the same answer. Students' answers have similarities with other students, namely 15% of 34 students.

In another sense, one answer can be put forward by between 4-5 students. Based on the research results, this kind of situation is categorized as "quite creative"(6,11,38).

Original thinking is an important component of creative thinking. Students must come up with ideas that are unique and different from others (11,15,50). Students must think unusual in order to come up with unique ideas (6,9). Learning that gives students the opportunity to play an active role and provide contextual problems can improve students' original thinking. This is consistent with the assumption that creative thinking is a cognitive process that can be stimulated through learning (6,7,14).

TABLE 4. Recapitulation of students' answers on originality creative thinking skill

Indicator	Student Answer	Category
Presented with a form of mosquito spray, students can think in an original way to get the spray results with high speed and wide.	Increase the pressure on T so that the wind output at A will be large	Quite Creative
	Adding thrust to thrust T	
	Make a flattened hole in hole A so that the water comes out spread out.	Creative
	Make hole A with a small area so that it will produce a high wind speed. This wind will produce a low pressure at the end of pipe B so that the water can rise.	
	The hole in Part B is made like an oval so that when the water comes out it can spread out	
	Fill the liquid completely into B so that it can be reached by pipe B	
	Increase the length of the T tube so that the gas is sprayed a lot	
	Changing the shape of the spray tube with a flattened shape and the hole part A is made small and widened so that the water that comes out will widen	
	Adding several holes in section A which are arranged horizontally so that the wind output is more than one. The water that comes out of B will gush in all directions.	
	Make a spray tube with a conical shape so that the air that comes out is high speed	
The output pipe, with parts A and B, are flattened so that the liquid that comes out will spread out		

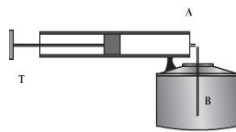


FIGURE 1. Insect spray

Based on the difficulties found, the researcher recommends using IBL-STEM with FA on more than one physics material. With the continuous use of IBL STEM, researchers believe that students' creative thinking skills will increase along with the increase in students' confidence to express ideas. The IBL-STEM with FA intervention is more effective if it is supported by a good duration of time and learning preparation. In addition, feedback from teachers and students plays an important role in improving students' creative thinking skills.

CONCLUSION

Creative Thinking Ability through IBL-STEM with FA shows good results. The syntax combination of IBL-STEM with FA is designed to improve every component of students' creative thinking skill including fluency (thinking fluently), flexibility (thinking flexible), originality (original thinking), and elaboration (thinking in detail). Students have the opportunity to come up with ideas to find new knowledge. The freedom of students in determining the form of learning can improve students' creative thinking skills. Students' creative thinking skills increased significantly with N-gain = 0.64 (medium category) and d-effect = 5.05 (very large category). After learning, students find it difficult to think flexibly (flexibility) to develop tools based on the Principle of Continuity and develop an effective and environmentally friendly chimney design. In addition, students still find it difficult to think in original terms to determine the spray results at high speed and widely.

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