# Improving creative thinking skill of fluid dynamic through IBL-STEM with formative assessment

Cite as: AIP Conference Proceedings **2330**, 050016 (2021); https://doi.org/10.1063/5.0043128
Published Online: 02 March 2021

**Gilang Adi Permana, Parno, Arif Hidayat, et al.**

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

Gilang Adi Permana[1, a)], Parno[1, b)], Arif Hidayat[1, c)], and Marlina Ali[2, d)]

[1]*Physics Education, Universitas Negeri Malang, Indonesia*
[2]*School Education, Universiti Teknologi Malaysia, Malaysia*

[a)]permanagilangadi@gmail.com
[b)]Corresponding author: parno.fmipa@um.ac.id
[c)]arif.hidayat.fmipa@um.ac.id
[d)]p-marlina@utm.my

**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

*The 4th International Conference on Mathematics and Science Education (ICoMSE) 2020*
AIP Conf. Proc. 2330, 050016-1–050016-8; https://doi.org/10.1063/5.0043128
Published by AIP Publishing. 978-0-7354-4074-6/$30.00

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, 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 alternativeanswer |
| | 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 |
|---|---|---|---|
| *Fluency* | Creative | 3 | Mentioning/writing down three different ideas, suggestions or alternative answers |
| | Very Creative | 4 | Mentioning/writing down fiour or more different ideas, suggestions or alternative answers |
| *Flexibility* | 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 |
| *Originality* | 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 |
| *Elaboration* | 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 Homogenity 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 thingking 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 Creative |
| | Fire hose | |
| | Watering hose for plants | Quite Creative |
| | Fire hose | |
| | 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 Creative |
| | Fire officer hose whose cross-sectional area can be changed according to the arrangement to reach the point of fire | |
| | 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 thingking 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 Creative |
| | Build factories that are far from residential areas | |
| | Build an environmentally friendly factory | |
| | Using environmentally friendly materials | |
| | Added a fan on the exhaust engine to push the smoke out of the chimney | Quite Creative |
| | The chimneys are made in a cone shape according to the Bernuollli 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 | |
| | 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 | Creative |
| | 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 | |
| | 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)

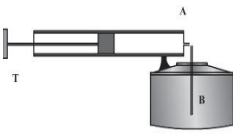
Third, students find it difficult to think in original terms to get high and wide speed on the mosquito spray. The pretest results showed that 67.65% were not creative and 32.35 were less creative. After the posttest, as many as 91.8% of students were categorized as quite creative and 8.82% were categorized 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 thingking 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.   **FIGURE 1**. Insect spray | 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. | |
| | 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 | Creative |
| | 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 | |

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.

## ACKNOWLEDGEMENTS

The author would like to acknowledge the support from the Direktur Riset dan Pengabdian Masyarakat (DRPM) under a grant number of 10.3.60/UN32.14/LT/2020 from the Ministry of Education and Culture Indonesia

## REFERENCES


1. Brown A. Engaging students as partners in developing online learning and feedback activities for first-year fluid mechanics. Eur J Eng Educ. 2018 Jan 2;43(1):26–39.
2. Rahman A. A blended learning approach to teach fluid mechanics in engineering. :9.
3. Suarez A, Kahan S, Zavala G, Marti AC. Students' conceptual difficulties in hydrodynamics. Phys Rev Phys Educ Res. 2017 Nov 28;13(2):020132.
4. Makrufi A, Hidayat A. Analisis Kemampuan Pemecahan Masalah Siswa pada Materi Fluida Dinamis. :9.
5. Sutaphan S, Yuenyong C. STEM Education Teaching approach: Inquiry from the Context Based. J Phys Conf Ser. 2019 Oct;1340:012003.
6. Kind PM, Kind V. Creativity in Science Education: Perspectives and Challenges for Developing School Science. Stud Sci Educ. 2007 Jan;43(1):1–37.
7. Yazar Soyadı MÖ. The Effectiveness of SCAMPER Technique on Creative Thinking Skills. J Educ Gift Young Sci. 2016 Jun 15;4(1):31–31.
8. Trilling B, Nilsson P, Gro J. Maya Bialik Charles Fadel. :18.
9. Wechsler SM, Saiz C, Rivas SF, Vendramini CMM, Almeida LS, Mundim MC, et al. Creative and critical thinking: Independent or overlapping components? Think Ski Creat. 2018 Mar;27:114–22.
10. Acedo C, Hughes C. Principles for learning and competences in the 21st-century curriculum. Prospects. 2014 Dec;44(4):503–25.
11. Nur S, ZubaiDah S, Mahanal S, Rohman F. ERCoRe Learning Model to Improve Creative-Thinking Skills of Preservice Biology Teachers. J Educ Gift Young Sci. 2020 Mar 15;549–69.
12. Wibowo FC, Suhandi A, Harjoto B. Penerapan Model Project Creative Learning (PCL) untuk Mengembangkan Keterampilan Berpikir Kreatif Konsep Listrik Magnet. 2013;7.
13. Rusilowati A. Pengembangan Kreativitas Siswa dalam Membuat Karya IPA melalui Model Pembelajaran Problem Based-Instruction di SMP. 2009;6.
14. Mahmud I, Islam YM, Rawshon S. Engineering creativity by using computer aided Mindmap. Am J Eng Res. 2013;6.
15. Putri ND, Hidayat A, Koes S. Identifying of Student's Creative. :10.
16. Deta UA, Widha S. Pengaruh Metode Inkuiri Terbimbing dan Proyek, Kreativitas, serta Keterampilan Proses Sains terhadap Prestasi Belajar Siswa. 2013;7.
17. Rodríguez G, Pérez N, Núñez G, Baños J-E, Carrió M. Developing creative and research skills through an open and interprofessional inquiry-based learning course. BMC Med Educ. 2019 Dec;19(1):134.
18. Sandika B, Fitrihidajati H. Improving creative thinking skills and scientific attitude through inquiry-based learning in basic biology lecture toward student of biology education. J Pendidik Biol Indones. 2018 Mar 26;4(1):23.
19. Kurniawan AD. Metode Inkuiri Terbimbing dalam Pembuatan Media Pembelajaran Biologi untuk Meningkatkan Pemahaman Konsep dan Kreativitas Siswa SMP. 2013;4.
20. Pedaste M, Mäeots M, Siiman LA, de Jong T, van Riesen SAN, Kamp ET, et al. Phases of inquiry-based learning: Definitions and the inquiry cycle. Educ Res Rev. 2015 Feb;14:47–61.
21. Santofani A, Rosana D. Pengembangan Tes Kreativitas pada Pembelajaran Fisika dengan Pendekatan Inkuiri pada Materi Teori Kinetik Gas. J Inov Pendidik IPA. 2016;11.
22. Narueponjirakoon P, Eamoraphan S. A Comparative Study on Self-Efficacy For Performing Learning Inquiry Tasks and Attitudes Toward Learning Chemistry Through Inquiry-Based Laboratories In Grades 9-12 Students at Concordian International School, Thailand. :9.
23. Kelley TR, Knowles JG. A conceptual framework for integrated STEM education. Int J STEM Educ. 2016 Dec;3(1):11.
24. Rustaman NY, Afianti E, Maryati S. STEM based learning to facilitate middle school students' conceptual change, creativity and collaboration in organization of living system topic. J Phys. :9.
25. Eratay E. An Investigation on the Creativity of Turkish Fine Arts High School Students: A Case Study. J Educ Gift Young Sci. 2017 Jun 15;5(2):55–70.
26. Rivai HP, Yuliati L. Penguasaan Konsep dengan Pembelaj1a05r9 an STEM Berbasis Masalah Materi Fluida Dinamis pada Siswa SMA. :9.
27. Henriksen D. Full STEAM Ahead: Creativity in Excellent STEM Teaching Practices. STEAM. 2014 Feb 28;1(2):1–9.

28. Mordeno IC, Sabac AM, Roullo AJ, Bendong HD, Buan A, Yuenyong C. Developing the Garbage Problem in Iligan City STEM Education Lesson Through Team Teaching. J Phys Conf Ser. 2019 Oct;1340:012046.
29. Villaruz EJ, Cardona MCF, Buan AT, Barquilla MB, Yuenyong C. Ice Cream STEM Education Learning Activity: Inquiry from the Context. J Phys Conf Ser. 2019 Oct;1340:012092.
30. Bennett RE. Formative assessment: a critical review. Assess Educ Princ Policy Pract. 2011 Feb;18(1):5–25.
31. James M. Embedding Formative Assessment in Classroom Practice. In: Maclean R, editor. Life in Schools and Classrooms [Internet]. Singapore: Springer Singapore; 2017 [cited 2019 Oct 16]. p. 509–25. Available from: http://link.springer.com/10.1007/978-981-10-3654-5_31
32. Decristan J, Klieme E, Kunter M, Hochweber J, Büttner G, Fauth B, et al. Embedded Formative Assessment and Classroom Process Quality: How Do They Interact in Promoting Science Understanding? Am Educ Res J. 2015 Dec;52(6):1133–59.
33. Creswell JW. Educational research: planning, conducting, and evaluating quantitative and qualitative research. 2013.
34. Alghafri ASR, Ismail HNB. The Effects of Integrating Creative and Critical Thinking on Schools Students' Thinking. Int J Soc Sci Humanity. 2014;4(6):518–25.
35. Astutik S, Mahdiannur MA, Prahani BK. Improving science process skills of junior high school students through the implementation of collaborative creativity learning (CCL) model in physics learning. J Phys. 2018;7.
36. Perry A, Karpova E. Efficacy of teaching creative thinking skills: A comparison of multiple creativity assessments. Think Ski Creat. 2017 Jun;24:118–26.
37. Morgan GA, editor. SPSS for introductory statistics: use and interpretation. 2nd ed. Mahwah, NJ: Lawrence Erlbaum; 2004. 211 p.
38. Hu W, Adey P. A scientific creativity test for secondary school students. Int J Sci Educ. 2002 Apr;24(4):389–403.
39. Zubaidah Si, Fuad NM, Mahanal S, Suarsini E. Improving Creative Thinking Skills of Students through Differentiated Science Inquiry Integrated with Mind Map. J Turk Sci Educ. 2017 Jul 8;15.
40. Damawati NAC, Juanda EA. The Effect of Inquiry Based Learning on The Reasoning Ability of Grade VII Students about Heat Concept. 2016;8.
41. Docktor JL, Mestre JP. Synthesis of discipline-based education research in physics. Phys Rev Spec Top - Phys Educ Res. 2014 Sep 16;10(2):020119.
42. Ayala CC, Shavelson RJ, Araceli Ruiz-Primo M, Brandon PR, Yin Y, Furtak EM, et al. From Formal Embedded Assessments to Reflective Lessons: The Development of Formative Assessment Studies. Appl Meas Educ. 2008 Sep 30;21(4):315–34.
43. Ediyanto E. Siklus Prapembelajaran Model Penilaian Formatif Web-Based pada Pembelajaran Fisika Materi Suhu dan Kalor Untuk Siswa SMK Kelas X. J Pendidik Fis Indones. 2016 Oct 30;12(2):126–36.
44. Saputra O, Setiawan A, Rusdiana D. Identifikasi Miskonsepsi Siswa Sekolah Menengah Atas (SMA) pada Topik Fluida Dinamis. 7(3):12.
45. Hsieh YC. Learning Foremost Knowledge of Fluid Mechanics with Multiple Representations. Adv Mater Res. 2012 Nov;591–593:2384–7.
46. Daud AM. Creativity in Science Education. 2012;8.
47. Sahin A, Gulacar O, Stuessy C. High School Students' Perceptions of the Effects of International Science Olympiad on Their STEM Career Aspirations and Twenty-First Century Skill Development. Res Sci Educ. 2015 Dec;45(6):785–805.
48. Kenett YN, Levy O, Kenett DY, Stanley HE, Faust M, Havlin S. Flexibility of thought in high creative individuals represented by percolation analysis. Proc Natl Acad Sci. 2018 Jan 30;115(5):867–72.
49. Schmidt AL. Creativity in Science: Tensions between Perception and Practice. Creat Educ. 2011;02(05):435–45.
50. Lucchiari C, Sala PM, Vanutelli ME. The effects of a cognitive pathway to promote class creative thinking. An experimental study on Italian primary school students. Think Ski Creat. 2019 Mar;31:156–66.