Analysis of High School Students' Creative Thinking Ability in Dynamic Fluid Topics

Bintan Nuril Irvaniyah*, Oktavina Pandango, Mohammad Jazil Saidan, & Parno
Physics Education Study Program, State University of Malang, Indonesia
*Corresponding Author: bintan.nuril.2403218@students.um.ac.id

Received: 5thJanuary 2025; **Accepted**: 18th March 2025; **Published**: 19th March 2025
DOI: https://dx.doi.org/10.29303/jpft.v11i1.8337

Abstract *– Creative thinking ability (CTA) is essential for generating innovative solutions to real-world challenges. This study analyzes high school students' CTA on dynamic fluid topics, focusing on subtopics of flow rate, continuity principle, and Bernoulli's principle. A quantitative survey was conducted with 33 students from a high school in Malang, Indonesia, using a validated essay-based Creative Thinking Ability Test (reliability: 0.880). Descriptive statistics and rubric-based scoring (0–4 scale) categorized CTA levels. Results indicated an overall low CTA (average score: 26.52/100), with flow rate subtopic scoring "very low" (18.18%), while continuity and Bernoulli's principles scored "low" (34.85% and 26.01%). Indicators like fluency, flexibility, originality, and elaboration were underdeveloped, as students struggled to generate diverse ideas, link concepts, and elaborate solutions. Dominant teacher-centered learning and fragmented conceptual understanding were identified as contributing factors. The study recommends integrating authentic problem-based learning (aPBL), project-based learning (PjBL), and technology-enhanced simulations to foster CTA. These findings highlight the urgency of reforming physics pedagogy to align with 21st-century skill demands.*

Keywords*: Creative Thinking Ability; Dynamic Fluid; Authentic Problem.*

INTRODUCTION

Physics is a subject that requires a deep understanding of interconnected concepts rather than mere memorization (Lestari & Kusumaningrum, 2019). Among the various physics topics, dynamic fluid presents a unique challenge for students due to its abstract and complex nature (Dewi et al., 2021). This topic involves essential principles such as fluid discharge, the continuity equation, and Bernoulli's Law (Walker, 2022). However, despite their significance, students often struggle to grasp these concepts, leading to persistent misconceptions (Aliyah et al., 2022).

One of the most common misconceptions is the belief that the faster a fluid moves, the higher its pressure, which contradicts Bernoulli's principle (Suarez et al., 2017). Fluid discharge is also frequently misunderstood with flow rate by students, and this complicates it for them to tackle real fluid dynamics problems (Ramadhani et al., 2022). The challenges are due to the fact that students primarily memorize equations and fewer comprehend concepts. Therefore, they are unaware of how to utilize their skills in a creative manner in solving problems (Parno et al., 2021).

With the current dynamic world, CTA (Creative Thinking Ability) is more necessary than ever, especially in the curriculum for science. The skill enables students to scrutinize a range of possibilities, develop new solutions, and connect abstract concepts with practical use (Kiraga, 2023). Despite its necessity, research shows that students' CTA for physics is very low (Hanni et al., 2023). Different studies have also been done on CTA in other physics topics, e.g., motion (Putri et al., 2023), static fluids (Permana et al., 2021), and energy (Malik et al., 2019). However, there is not much work on CTA in the context of dynamic fluids.

Students with creative thinking abilities are encouraged to use their imaginations to come up with original concepts, theories, or experiments (Kiraga, 2023). Optimal CTA will enable creative individuals to face and solve problems in various situations (Athifah & Syafriani, 2019). This skill is related to the ability to solve problems from multiple perspectives (Kiraga, 2023; Abidaturrosyidah et al., 2024). With this skill, students can find alternative solutions and are able to innovate in learning (Henriksen et al., 2017).

In addition, students' creative thinking ability are still relatively low (Hanni et al., 2018). Some research on learning models or strategies has also been conducted to construct creative thinking skills, including problem-based learning (Wenno et al., 2021), project-based learning (Saefullah et al., 2021;), technology-based learning (Putri et al., 2023), cooperative learning type NHT (Yuli et al., 2018), and the STEM approach (Saefullah et al., 2021).

While previous efforts have been encouraging, research that has explicitly investigated students' Creative Thinking Ability (CTA) in fluid dynamics via a systematic evaluation has been limited. In an attempt to fill this void, this research aims to investigate students' CTA in dynamic fluids, identify their specific challenges, and recommend effective teaching strategies. Unlike the previous research, this study employs a systematic assessment framework that measures CTA against four significant dimensions: fluency, flexibility, originality, and elaboration (Pratiwi et al., 2020). Through the application of a description test, this research allows close scrutiny of the students' answers, enabling detailed characterization of the students' inventive thinking ability. As creative thinking plays a significant role in the learning process, the formation of these competencies must receive special attention in the physics curriculum. The result of this study is expected to contribute to the design of learning models and instructional phase structures that foster the development of students' creative thinking in physics education

RESEARCH METHODS

This research is a non-experimental study using a survey design (Fernando, Parno and Diantoro, 2024). This survey of creative thinking ability involved 33 students at a high school in Malang, Indonesia who had taken the topic of dynamic fluids. The researcher developed the research instrument based on indicators of creative thinking ability, namely (1) fluency, (2) flexibility, (3) originality, and (4) elaboration. The test consists of 12 description questions that include indicators of creative thinking and dynamic fluid subtopics, namely the venturi meter, Bernoulli's law, and discharge. The results of the question instrument analysis are based on innovative thinking ability, validity test, difficulty test, and differentiation test in Table 1.

Table 1. Item indicator characteristics of creative thinking ability

Indicator	Item	Validity	Difference level	Difficulty level	Reliability Cronbach's Alpha
1	1	.000	.516	.348	.880 (high)
3	2	.000	.469	.227	
4	3	.047	.609	.348	
3	4	.000	.453	.402	
1	5	.001	.469	.356	
4	6	.000	.563	.341	
2	7	.000	.438	.295	
2	8	.000	.594	.326	
2	9	.000	.469	.227	

Indicator	Item	Validity	Difference level	Difficulty level	Reliability Cronbach's Alpha
1	10	.000	.375	.106	
1	11	.005	.375	.091	
4	12	.001	.328	.114	

Table 1 shows that the instrument has a reliability of 0.880 with a high category. All questions tested valid ($p < 0.05$), and the level of difficulty ($0.3 < p < 0.6$). Meanwhile, the differentiating power results show that questions number 1 to 9 have good criteria, and questions number 10 to 12 have moderate criteria. This good enough differentiating power shows that the instrument is suitable for measuring creative thinking ability in research.

Data collection was conducted on students who had studied the topic of dynamic fluid so that students' conceptual understanding of this topic could be measured in relation to students' creative thinking ability. Gender analysis was not conducted in this study because the main focus was on measuring creative thinking abilities in general without considering demographic factors such as gender. However, gender analysis can be a relevant addition to further studies to explore variations in creative thinking abilities based on gender. The results of this study cannot be generalized directly to the entire population of 12th-grade students in Malang due to limitations in sample representation.

The assessment used a 0-4 scale developed in research (Pratiwi et al., 2020) which was adjusted to each indicator of creative thinking ability. In the activity of analyzing student answers, the researcher uses an assessment rubric that has been prepared based on the level of innovative thinking ability listed in Table 2.

Table 2. Scoring rubric of creative thinking ability

Indicator	Criteria	Score
Fluency	• Mentions/inscribes at least five distinct concepts, solutions, or alternate responses.	4
	• Mentions/inscribes at least three distinct concepts, solutions, or alternate responses.	3
	• Mentions/inscribes some of concepts, fixes, or somewhat similar alternatives.	2
	• Mentions/inscribes a single concept, fix, or different response.	1
	• Either doesn't respond at all or gives a wrong response.	0
Flexibility	• Composes a variety of logical alternative solutions to tackle the topic at question from multiple perspectives.	4
	• Composes a variety of logical alternative solutions to tackle the topic at question from multiple perspectives.	3
	• From multiple perspectives, write an array of reasonable but irrelevant alternate solutions to the given situation.	2
	• Providing just one point of view, write one alternate solution that is reasonable and applicable to the issue at question.	1
	• Either doesn't respond at all or gives a wrong response.	0
Originiality	• Mentioned/wrote a few original concepts that are intriguing, rational, somewhat fresh, and pertinent to the issue at issue.	4
	• Mentioned/wrote down a few original concepts that are intriguing, rational, and reasonably recent but less pertinent to the issue at issue	3
	• Mentioned/wrote down a few somewhat intriguing original concepts that are reasonably innovative, reasonably logical, and somewhat pertinent to the issue at issue	2
	• Mentioned/ wrote a typical concept that makes sense and is pertinent to the issue at issue.	1

Indicator	Criteria	Score
Elaboration	• Either doesn't respond at all or gives a wrong response.	0
	• Provides clarification on a variety of logical aspects of the concept, rendering it easier to understand and implement.	4
	• Provides clarification on one logical aspect of the concept, rendering it easier to understand and apply.	3
	• Provides a few acceptable details about the notion, but these don't add enough context to the core idea, thus these don't clarify it.	2
	• The idea formulation cannot be used effectively since it lacks additional information.	1
	• Either provides an incorrect response or no response at all.	0

The scores obtained by students are based on the assessment rubric above, and then scale transformation is carried out to determine the level of students' creative thinking ability. The results of student scores are grouped according to the level of creative thinking ability based on the interval (Nurhamidah et al., 2018) in the Table 3 below.

Table 3. Students' creative thinking ability level

Interval (%)	Category of ability
81-100	Very creative
61-80	Creative
41-60	Moderate
21-40	Low
0-20	Very low

RESULTS AND DISCUSSION

Table 4 describes the students' capacity for creative thinking about dynamic fluid.

Table 4. Descriptive statistics of students' creative thinking ability

Information	Score
Min	0.00
N	33
$\bar{x}$	26.52 (low)
SD	19.31
Max	64.60

Table 4 shows that the average results of all students who have studied the topic of dynamic fluids are at a low level. The results of this category are lower than previous studies, namely on dynamic fluid material (Permana et al., 2021) and other materials (Fernando, Parno and Diantoro, 2024). Indeed, this dynamic fluid material is considered difficult because of the existing concepts (Dewi et al., 2021). The standard deviation is quite large, indicating that students' creative thinking abilities are quite varied, so that the maximum value of students is obtained at a fairly creative level. This is because the learning model is still dominated by the teacher, and students are less given the opportunity to explore concepts independently, which results in students finding it difficult to develop their own conceptual framework, which has an impact on their low creativity in thinking and solving physics problems (Batlolona & Diantoro, 2023). In addition, it shows that physics learning has not fully empowered students' mental models, which play an important role in building deeper conceptual understanding and creative thinking skills. If students' mental models are not well developed, they will have difficulty in thinking creatively to solve physics problems (Batlolona & Diantoro, 2023).

The study results indicate creative thinking ability on the flow rate subtopic of 18.18%, continuity principle of 34.85%, and Bernoulli's principle of 26.01%. It appears that the flow rate subtopic is at a very low level, while the continuity principle and Bernoulli's principle subtopics are at a low level in the creative thinking ability category. This is consistent with earlier studies on students' conceptual knowledge of dynamic fluids, students' understanding of the discharge subtopic is lower than on the Bernoulli principle (Dewi et al., 2019). This is due to students' lack of mastery of the concept of discharge and ignorance of basic arithmetic, including the relationship between discharge, velocity, and cross-sectional area. Students experience more difficulty on the Discharge subtopic than the Bernoulli Principle because Flow Rate is often considered simple and intuitive, students tend to understand the concept superficially and do not master the mathematical aspects and continuity principles well (Dewi et al., 2019). Likewise, students' creative thinking abiliies are in line with research Nugroho et al. (2023), that on average the indicators of creative thinking skills are in the very low category. This lack of understanding of the concept causes students to be less able to provide creative solutions on the flow rate subtopic instrument test.

Another result of this study is the distribution of scores and averages of students' creative thinking ability. The results of the score distribution and the average of each creative thinking indicator are presented in Tables 5 and 6.

Table 5. Distribution of score achievements and average score of students' creative thinking ability indicators

Subtopic	Item	Creative thinking indicators	% score				
			0	1	2	3	4
Flow rate	2	Originality	54.55	18.18	15.15	6.06	6.06
	9	Flexibility	57.58	18.18	6.06	12.12	6.06
	11	Fluency	69.70	9.09	3.03	15.15	3.03
Continuity Principle	3	Elaboration	39.39	18.18	18.18	12.12	12.12
	4	Originality	21.21	21.21	36.36	18.18	3.03
	8	Flexibility	42.42	15.15	15.15	24.24	3.03
Bernoulli's Principle	1, 5, 10	Fluency	38.38	23.23	24.24	10.10	4.04
	6, 12	Elaboration	56.06	10.61	16.67	10.61	6.06
	7	Flexibility	33.33	27.27	27.27	12.12	0.00
Average score			45.85	17.90	18.01	13.41	4.83

Table 6. Average score of each indicator based on the results of all student scores

Item	Creative thinking indicators	% Average score
1, 5, 10, 11	Fluency	22.54
7, 8, 9	Flexibility	28.28
2, 4	Originality	31.44
3, 6, 12	Elaboration	26.77

Based on Table, it shows that in general student answers are in the score range of 0. This demonstrates that most pupils cannot offer answers or assertions on the issues raised in each topic. On the subtopic of Flow Discharge pressure, the originality indicator shows that students tend to get a score of 0, which means that they do not respond or the answer is wrong, it can be said that they have not been able to create unique and interesting ideas that are relevant to the problems presented, such as the design of Galileo's thermometer. This is in accordance with previous research (Sugiyanto et al., 2018) on biology education. In the flexibility indicator, most of the students' answers received a score of 0, meaning that most of them have not been able to provide answers that are relevant to the problem at hand. As for the fluency indicator, students' answers tend to get a score of 0, which in this case shows that students have not been able to offer ideas, suggestions or alternative answers to the problems presented.

On the subtopic of the Law of Continuity, the Flexibility indicator shows that most students' answers score between 0 and 3, which means that some students tend to give more wrong answers or do not answer, or some students can provide several ideas, solutions, statements, or alternative answers that are quite logical to a problem presented, for example the principle of aircraft lift force. In the elaboration indicator, students' answers tended to be in the scores 0 to 3, indicating that some students had not been able to provide logical details or new ideas along with details including alignment with the concepts used to provide new functions and even tended to give more wrong answers or did not answer, such as in the case of turbines. Meanwhile, in the originality indicator, students' answers tend to be at score 3, which means that students have been able to provide unique and interesting ideas even though they are not fully relevant to the problem, for example, designing venturi pipes to irrigate rice fields. Based on previous research (Suarez et al., 2017) that on Continuity material students experience some difficulties so that coming up with ideas, solutions and relevant statements will also tend to have difficulty.

On the Bernoulli's Azaz subtopic, the fluency indicator shows that students' answers tend to be within the score of 0 to 2. This means that students do not answer or give wrong answers, or only provide a few ideas, solutions, statements, or alternative answers that are relatively similar to each other for the problems presented, such as those related to venturimeters. This is in accordance with previous research (Ningrum & Jumadi, 2024). Whereas in the flexibility indicator, the majority of students' answers are within the score of 0 to 2, which indicates that students do not answer or provide wrong answers, or students can only provide one answer that is quite logical and relevant from one perspective, there are also students who provide several logical alternative answers but are less relevant to the problem presented, such as in the case of comparing people who swallow in the sea and lake. This is in accordance with previous research (Qodari et al., 2022). Furthermore, for the elaboration indicator, students' answers tend to be in the 0 score, which means that students do not answer or give wrong answers, or they have not been able to add new details or ideas to existing technology, such as the pressure in an airplane cabin.

The results above show the range of students' creative thinking abilities from the highest to the lowest, as presented in Table 6, namely originality and fluency. Based on previous research (Qodari et al., 2022) shows that the results of the analysis of the originality indicator get a smaller percentage of results and for the flexibility and fluency indicators have a greater percentage result, this is inversely proportional to the results of this study. In the results of this study, the fluency indicator is the lowest indicator because students are less able to propose alternative answers to existing problems. This is because students do not understand the concept of dynamic fluid deeply which results in students having difficulty in pouring as many ideas as possible in the problems presented.

Fluency indicators require the ability to generate many ideas in a short period of time, while flexibility requires the ability to think from multiple perspectives. Both of these abilities require diverse thinking exercises. The low fluency and flexibility indicators were caused by the fact that students were not used to questions that required them to develop multiple solutions and think from multiple perspectives (Nugroho et al., 2023). Another influencing factor is that the concepts that students learned previously are still fragmentary, so they have difficulty in connecting various concepts and applying them flexibly in various situations (Batlolona & Diantoro, 2023). Fluency indicators need to be improved, because an idea or concept needs to be elaborated and more detailed things added to clarify the concept. Learning project planning can improve fluency indicators by allowing students to create detailed stages (Nita & Irwandi, 2021).

The score distribution in Table 5 reinforces the research findings that the highest achievement scores on all creative thinking indicators vary widely. However, the dominant student creative thinking score is at score 0, which reaches 45%. This shows that students have not been able to provide ideas or solutions to a given problem or phenomenon. Creative thinking skills can be improved by practicing thinking about something, namely 'problems' (Newton et al., 2022). This can be improved through the use of problem-based learning models (Habibi et al., 2020), varied learning approaches (Stevenson et al., 2014), and encouraging students to work in groups, as the exchange of ideas can produce innovative solutions (Coursey et al., 2019). Once children are given the chance to think differently, their creativity and originality will continue to grow. Student’s should be encouraged to think creatively, employ fresh perspectives, have the opportunity to offer original concepts and solutions, make unconventional queries, and attempt to provide presumptuous responses (Handayani et al., 2021).

In another study, students' difficulties were mapped on each problem on the topic of dynamic fluid. The results of mapping the difficulty of creative thinking ability on each problem are presented in Table 7.

Table 7. Mapping student difficulties in creative thinking skills on fluid topics

Subtopic	Item	Creative Thinking Indicators	Conclusion of Student Difficulties in Each Question	Category of Ability
Flow Rate	2	Originality	Students try to come up with unique and pertinent ideas for problems about using technology to raise water pressure.	Very Low
	9	Flexibility	Students try to offer rational, pertinent concepts, recommendations, or substitute solutions to address the issue of oxygen scarcity in fish farming.	
	11	Fluency	Students find it difficult to logically explain the occurrence of pipes in oil factories, and they have less difficulty connecting the issue to flow rates.	
	3	Elaborations	Students attempt to enhance the waterwheel's current concept by adding features or embellishments.	
Continuity Principle	4	Originality	Students work hard to come up with unique, creative, and pertinent solutions for problems about occurrences in aeroplane cabins.	Low
	8	Flexibility	Students need help to come up with rational solutions or alternate ideas for the issue of dyspnea at varying elevations.	
	1	Fluency	Pupils need help to relate concepts to the Bernoulli principle and require assistance in offering rational solutions, recommendations, or other solutions regarding the issues with the venturi meter gadget.	

Subtopic	Item	Creative Thinking Indicators	Conclusion of Student Difficulties in Each Question	Category of Ability
Bernoulli's Principle	5	Fluency	Pupils are less able to relate concepts to the Bernoulli principle and require assistance in offering rational solutions, recommendations, or other solutions regarding the issues with the venturi meter gadget.	Low
	6	Elaborations	Students require assistance in connecting the issue to Bernoulli's principle.	
	7	Flexibility	While on the train station platform, students require assistance developing rational and pertinent solutions.	
	10	Fluency	To explain the phenomena of aeroplanes floating on the sea's surface, students must contribute rational and pertinent ideas, proposals, or alternate solutions.	
	12	Elaboration	Students attempt to enhance the current concept by adding features or details to the venturi meter.	

According to Table's mapping, students need help to offer pertinent solutions or ideas for a particular issue. When given a problem, students are only able to provide ideas or solutions from one point of view; they find it difficult to relate the physics concepts of flow velocity, continuity principle, and Bernoulli principle to the existing problem; students also experience difficulties in adding details to perfect existing ideas. The average of each indicator of creative thinking ability is in the medium category, which indicates student difficulty, so students can provide a logical and relevant idea but are less able to provide several logical and relevant ideas. This proves that the creative thinking ability of students at the high school level must receive more attention so that it must continue to be trained and improved.

The originality indicator is found in question 2 and question 4. Question 2 involves technology that uses dynamic fluid principles to increase water pressure in the channel. Question 4 involves a phenomenon in the cabin of an aeroplane that will activate the air pressure control system in the cabin before reaching a cruising altitude of about 35,000 feet. In the originality indicator, students were asked to provide several logical and relevant answers from various points of view related to the problem. However, most students could only provide one or two answers that needed to be more logical and relevant to the problem. According to Table 5, score 0 dominates question number 2 with a percentage of 54.55%, while score 2 dominates question number 4 with 36.36%.

The flexibility indicator is found in question 7, 8, and question 9. Question 7 deals with standing too close to a railroad track as a train passes. Question 8 involves a problem when a person runs on two plains of different heights. Question 9 involved a problem in cultivation that lacks oxygen levels. In this indicator, students needed help to provide ideas or solutions that were logical and relevant to the problem. This is by the scores obtained in Table 5, where questions 7, 8 and 9 have a percentage of 33.33%, 42.42%, and 57.58%, respectively, on the zero score.

The creative thinking ability on the fluency indicator used questions 1, 5, 10 and 11. Question 1 relates to a venturimeter device that uses Bernoulli's principle. Question 5 involved a problem in the human ear when diving in two places with different densities. Question 10 involved an aeroplane that is not airborne but floating on the sea's surface. Question 11 involved a pipe phenomenon found in an oil factory. In this indicator, students were required to provide several logical and relevant ideas for the phenomenon presented. Based on Table 5, students gave illogical and irrelevant ideas about the phenomenon. This is demonstrated by the fact that most answers to questions 1, 5, 10, and 11 are zero.

In the Elaboration indicator, questions 3, 6 and 12 are used. Question 3 involves a phenomenon that uses river water flow to drive a waterwheel. Question 6 involved the phenomenon of an aeroplane lifting during take-off. Question 12 presents technology that can calculate fluid flow rates. Students are required to add new details or functions to improve existing functions so that they can be more useful. However, in this case, students needed help adding the details requested in the question. This can be seen in the elaboration indicator, where the majority scored 0, as shown in Table 5.

This finding shows that students' creative thinking skills in solving problems have yet to be fully developed, so in the learning process it is very important to design and create good learning strategies that are by the characteristics of students and growing demands. In the 4.0 era, students must have creative thinking skills because creative thinking skills are one of the 21st-century skills. Therefore, to improve students' creative thinking skills, it is necessary to apply appropriate learning models or strategies such as problem-based learning (PBL), project-based learning (PjBl) and the STEM approach.

Based on Table 7, the categorisation results show that the flow rate subtopic is in the "very low" category with a value of 18.18%. This study aligns with the pretest results from previous research (Permana et al., 2021). In the flow rate subtopic, students have not mastered the discharge concept and do not understand basic arithmetic, such as the relationship between velocity, cross-sectional area, and discharge. Furthermore, the continuity principle subtopic also aligns with the pretest results of previous research (Permana et al., 2021). The continuity principle has the characteristics of complex material and many implications in broad applications from various fields, so students are less able to provide creative solutions to the problems presented. The Bernoulli principle subtopic is in the "low" category, where these results align with previous research pretests (Permana et al., 2021). This is because students need to understand the ideal fluid flow, so they cannot apply Bernoulli's principle to the application of everyday life, which results in students not being able to provide creative solutions on this subtopic.

This study also has limitations, namely, the results of this study cannot be generalized to other schools because there are several limitations. First, the sample used in this study only came from one school. Therefore, the results of this study are more representative of the characteristics of students in that school and do not reflect the conditions of students in other schools that may have different learning environments, curricula, or levels of understanding. Secondly, learning behavior factors in each school can vary significantly. Each school has a different teaching approach, both in terms of the methods used by teachers, the facilities available, and the academic culture that develops. This affects the way students build their mental models and creative thinking abilities.

CONCLUSION

Based on the research discussion, it shows that students' creative thinking skills on the topic of dynamic fluid are classified as low. The diversity in student results, which vary significantly for each measure of creative thinking ability, supports this finding. The student's creative thinking ability on the flow rate subtopic is in the very low category, while it is in a low category on the continuity principle and Bernoulli principal subtopics. The low ability on the flow rate subtopic is thought to be caused by a lack of mastery of the concept of discharge and a superficial understanding of the mathematical aspects and the principle of continuity. Underprivileged students produce unique and interesting ideas (originality), provide answers relevant to the problem (flexibility), and provide ideas, suggestions, or alternative answers (fluency). In addition, students also have difficulty providing logical details or new ideas and their details (elaboration).

The low level of students' creative thinking skills on dynamic fluids shows that physics learning has not fully empowered students to develop their own conceptual framework and build a deeper understanding of concepts. The learning model is still dominated by teachers, and the lack of opportunities for students to explore concepts independently is thought to be a contributing factor. The study recommends integrating authentic problem-based learning (**a**PBL), project-based learning (PjBL), to enhance creative thinking ability in dynamic fluid topics.

ACKNOWLEDGMENT

We are pleased to thank the Universitas Negeri Malang for providing support for this research.

REFERENCES

Abidaturrosyidah, A., Nurdiyanti, N., Jumadi, J., Aldila, F. T., & Ulfa, S. M. (2024). Empowering Students' Creative At The Utilization of Moodle-H5P with Flipped Classroom in Global Warming Learning to Enhance Students' Creative Attitudes. *Jurnal Penelitian & Pengembangan Pendidikan Fisika*, *10*(2), 261–272. https://doi.org/10.21009/1.10205

Aliyah, R., Sudibyo, E., Suyatno, & Wasis. (2022). The Profile of Misconceptions Using Three Tier Diagnostic Test on Dynamic Fluid. *Journal of Physics: Conference Series*, *2392*(1), 012032. https://doi.org/10.1088/1742-6596/2392/1/012032

Athifah, D. & Syafriani. (2019). Analysis of students creative thinking ability in physics learning. *Journal of Physics: Conference Series*, *1185*, 012116. https://doi.org/10.1088/1742-6596/1185/1/012116

Batlolona, J. R., & Diantoro, M. (2023). Mental Models and Creative Thinking Skills in Students' Physics Learning. *Creativity Studies*, *16*(2), 433–447. https://doi.org/10.3846/cs.2023.14743

Coursey, L. E., Gertner, R. T., Williams, B. C., Kenworthy, J. B., Paulus, P. B., & Doboli, S. (2019). Linking the Divergent and Convergent Processes of Collaborative Creativity: The Impact of Expertise Levels and Elaboration Processes. *Frontiers in Psychology*, *10*, 699. https://doi.org/10.3389/fpsyg.2019.00699

Dewi, F. H., Samsudin, A., & Chandra, D. T. (2021). Developing FD-MT to investigate students' mental model on fluid dynamic concept: A Rasch model analysis. *Journal of Physics: Conference Series*, *2098*(1), 012020. https://doi.org/10.1088/1742-6596/2098/1/012020

Dewi, F. H., Samsudin, A., & Nugraha, M. G. (2019). An investigation of students' conceptual understanding levels on fluid dynamics using four-tier test. *Journal of Physics: Conference Series*, *1280*(5), 052037. https://doi.org/10.1088/1742-6596/1280/5/052037

Fernando, T. J., Parno, & Diantoro, M. (2024). Analysis of students' scientific reasoning ability on static fluid topics. *Journal of Physics: Conference Series*, *2684*(1), 012003. https://doi.org/10.1088/1742-6596/2684/1/012003

Habibi, H., Mundilarto, M., Jumadi, J., Gummah, S., Ahzan, S., & Prasetya, D. S. B. (2020). Project brief effects on creative thinking skills among low-ability pre-service physics teachers. *International Journal of Evaluation and Research in Education (IJERE)*, *9*(2), 415. https://doi.org/10.11591/ijere.v9i2.20531

Handayani, S. A., Rahayu, Y. S., & Agustini, R. (2021). Students' creative thinking skills in biology learning: Fluency, flexibility, originality, and elaboration. *Journal of Physics: Conference Series*, *1747*(1), 012040. https://doi.org/10.1088/1742-6596/1747/1/012040

Hanni, I. U., Muslim, Hasanah, L., & Samsudin, A. (2018). K-11 students' creative thinking ability on static fluid: A case study. *Journal of Physics: Conference Series*, *1013*, 012034. https://doi.org/10.1088/1742-6596/1013/1/012034

Henriksen, D., Richardson, C., & Mehta, R. (2017). Design thinking: A creative approach to educational problems of practice. *Thinking Skills and Creativity*, *26*, 140–153. https://doi.org/10.1016/j.tsc.2017.10.001

Kiraga, F. (2023). Literature Review: Efforts To Improve Creative Thinking Ability In Science Learning. *Integrated Science Education Journal*, *4*(2), 77–83. https://doi.org/10.37251/isej.v4i2.330

Malik, A., Denya Agustina, R., & Alisia Wardhany, W. (2019). Improving creative thinking skills of student related to the concept work and energy. *Journal of Physics: Conference Series*, *1175*, 012180. https://doi.org/10.1088/1742-6596/1175/1/012180

Newton, D. P., Nolan, S., & Rees, S. (2022). *Creative Thinking in University Physics Education:* IOP Publishing. https://doi.org/10.1088/978-0-7503-4028-1

Ningrum, D. I. P. C. & Jumadi. (2024). Development of Physics Websites Based on STEM Assisted of Google Sites on Momentum and Impulse Materials to Improve Creative Thinking Skills. *Jurnal Penelitian Pendidikan IPA*, *10*(9), 6766–6776. https://doi.org/10.29303/jppipa.v10i9.5168

Nita, R. S., & Irwandi, I. (2021). Peningkatan Keterampilan Berpikir Kreatif Siswa Melalui Model Project Based Learning (PjBL). *BIOEDUSAINS:Jurnal Pendidikan Biologi Dan Sains*, *4*(2), 231–238. https://doi.org/10.31539/bioedusains.v4i2.2503

Nugroho, P. S., Nasir, M., Syafi'i, M., & Erviyenni, E. (2023). Profile Perception of Student's Collaboration and Creative Thinking Skills in Physics. *Jurnal Penelitian Pendidikan IPA*, *9*(2), 775–779. https://doi.org/10.29303/jppipa.v9i2.3055

Nurhamidah, D., Masykuri, M., & Dwiastuti, S. (2018). Profile of senior high school students' creative thinking skills on biology material in low, medium, and high academic perspective. *Journal of Physics: Conference Series*, *1006*, 012035. https://doi.org/10.1088/1742-6596/1006/1/012035

Parno, Permana, G. A., Hidayat, A., & Ali, M. (2021). Improving Students Understanding on Fluid Dynamics through IBL-STEM Model with Formative Assessment. *Journal of Physics: Conference Series*, *1747*(1), 012008. https://doi.org/10.1088/1742-6596/1747/1/012008

Permana, G. A., Parno, Hidayat, A., & Ali, M. (2021). *Improving creative thinking skill of fluid dynamic through IBL-STEM with formative assessment*. 050016. https://doi.org/10.1063/5.0043128

Pratiwi, M., Siahaan, P., Samsudin, A., Aminudin, A. H., & Rachmadtullah, R. (2020). Introduction, Connection, Application, Reflection, Extension-Multimedia Based Integrated Instruction (ICARE-U): A Model to Improve Creative Thinking Skills. *International Journal of Psychosocial Rehabilitation*, *24*(08).

Putri, J. A., Parno, Marsuki, M. F., Hamimi, E., & Fitriyah, I. J. (2023). *Development of STEM-based animation interactive multimedia with feedback to improve students' creative thinking ability on motion topic*. 110002. https://doi.org/10.1063/5.0122527

Qodari, N. N., Sinaga, P., & Suhendi, E. (2022). *Analysis of creative thinking skills of high school students in dynamic fluid materials as the impact of distance learning during the Covid-19 pandemic*. 020022. https://doi.org/10.1063/5.0103684

Ramadhani, N., Simanullang, S. R., & Simbolon, dan V. A. Br. (2022). Identifikasi Kemampuan Siswa Dalam Pemecahan Masalah Miskonsepsi Pada Materi Fluida Dinamis di Tingkat SMA. *EduFisika*, *7*(2), 197–205.

Saefullah, A., Suherman, A., Utami, R. T., Antarnusa, G., Rostikawati, D. A., & Zidny, R. (2021). Implementation of PjBL-STEM to Improve Students' Creative Thinking Skills On Static Fluid Topic. *JIPF (Jurnal Ilmu Pendidikan Fisika)*, *6*(2), 149. https://doi.org/10.26737/jipf.v6i2.1805

Stevenson, C. E., Kleibeuker, S. W., De Dreu, C. K. W., & Crone, E. A. (2014). Training creative cognition: Adolescence as a flexible period for improving creativity. *Frontiers in Human Neuroscience*, *8*. https://doi.org/10.3389/fnhum.2014.00827

Suarez, A., Kahan, S., Zavala, G., & Marti, A. C. (2017). Students' conceptual difficulties in hydrodynamics. *Physical Review Physics Education Research*, *13*(2), 020132. https://doi.org/10.1103/PhysRevPhysEducRes.13.020132

Sugiyanto, F. N., Masykuri, M., & Muzzazinah. (2018). Analysis of senior high school students' creative thinking skills profile in Klaten regency. *Journal of Physics: Conference Series*, *1006*, 012038. https://doi.org/10.1088/1742-6596/1006/1/012038

Walker, J. (2022). *Halliday & Resnick Fundamentals of physics* (Twelfth edition. Extended edition). Wiley.

Wenno, I. H., Jamaludin, & Batlolona, J. R. (2021). The Effect of Problem Based Learning Model on Creative and Critical Thinking Skills in Static Fluid Topics. *Jurnal Pendidikan Sains Indonesia*, *9*(3), 498–511. https://doi.org/10.24815/jpsi.v9i5.20829

Yuli, Y., Sahidu, H., & Ayub, S. (2018). Pengaruh Model Pembelajaran Kooperatif Tipe Numbered Head Together (NHT) Berbantuan LKPD Terhadap Kemampuan Berpikir Kreatif Fisika Peserta Didik di SMAN 3 Mataram. *Jurnal Pendidikan Fisika Dan Teknologi*, *4*(1), 49–55. https://doi.org/10.29303/jpft.v4i1.455