

Students' creative thinking skills on the material of motion dynamics through STEM-PjBL

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Abstract

The ability to think creatively is an essential skill in the 21st century. This research aims to analyze students' creative thinking abilities by implementing Project-Based Learning Integrated with Science, Technology, Engineering, and Mathematics (STEM-PjBL) on motion dynamics material. The research method is descriptive qualitative, with data obtained through observation, interviews, and student worksheet documents. The research results show that two indicators are in a suitable category, namely fluency and authenticity, while the other two indicators, flexibility and elaboration, are in the poor category. Recommendations that can be given based on the results of this research include the need to integrate the STEM-PjBL method more deeply into physics learning to improve all indicators of creative thinking abilities, especially flexibility, and elaboration. This research emphasizes the importance of learning that prioritizes students as the center of learning to develop various essential creative thinking skills.

Keywords: Creative thinking skills, Dynamics of motion, STEM-Integrated Project Based Learning

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I. Introduction

The ability to think creatively is one of the 4C skills needed in the 21st century, including critical thinking and problem-solving, creativity, innovation, communication, and collaboration [1]. The ability to think creatively is a skill that can improve a person's ability to solve problems by creating something that already exists or is new [2]. Four indicators of creative thinking ability—fluency, flexibility, originality, and elaboration—are essential for students' in-depth understanding of concepts [3]. Creative thinking skills have a directly proportional relationship with students' ability to understand concepts. If a person's creative thinking skills are high, then the ability to accept new concepts will be easier with the various creative ways he has [4].

The STEM (Science, Technology, Engineering, and Mathematics) approach is widely used in learning physics. In its implementation, the STEM approach emphasizes solving problems related to everyday life and forming logical thinking in various fields of knowledge [5]. Learning using the STEM approach is learning that collaborates science, technology, engineering, and mathematics (STEM) in learning activities [6].

Currently, the curriculum that is widely used in schools is the independent curriculum, where one of the recommended learning models is Project Based Learning (PjBL) [7]. The PjBL model emphasizes the final result in the form of a product from a project carried out as a group in learning activities [6]. This model will train students to develop skills in problem solving when working on projects to produce products related to

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real life [8]. In addition, in the PjBL model students will be positioned as the center of learning, so that the mindset can develop [7].

The PjBL model in physics learning will run optimally if integrated with the STEM approach. According to Ref [9], STEM-integrated PjBL learning will train students to identify problems, search for important information, make plans, design, and make products as problem solutions. According to Ref [10], physics learning using the STEM integrated PjBL model can improve creative thinking skills. The stages of STEM-integrated PjBL are described in Table 1 as follows [11].

Table 1. Linkage of STEM integrated PjBL stages with creative thinking skills indicators

No	Syntax	Description	Indicators of creative thinking skills
1	Teacher Introduction	The teacher provides an introduction in the form of information about the material to be learned and the project to be made by the students.	Fluency and Flexibility
2	Objectives	The teacher conveys the learning objectives, then the students are asked to convey the learning objectives according to their understanding.	
3	STEM-Connections	The teacher relates the project to the STEM components, then asks the students to relate the STEM components in detail using their own language.	Flexibility and elaboration
4	Well-Defined Outcome	The teacher defines the learning outcomes and relates them to real life, then students read the case study and search for literature and think about the product that will be made in the project activity.	Fluency, Flexibility, and elaboration
5	Materials	Students determine the materials used to make the product and start designing the product.	Flexibility and originality
6	Engagement	Students are directly involved in the project.	Elaboration
7	Exploration	Students develop more in-depth questions about the research, then seek answers by testing the project and analyzing the constraints.	
8	Explanation	Students give an explanation of the project that has been made, then the teacher provides reinforcement.	Originality
9	Extension	The teacher asks questions related to the project and students answer the questions.	Fluency
10	Evaluation	The teacher gives feedback on students' work and asks students to improve their work.	Elaboration

Motion dynamics is one of the important materials in physics learning because it is widely applied in everyday life. In this material, students learn about motion and forces that cause an object to change position [12]. The concept of force and motion learned through Newton's Law is the basis of other physical sciences, so problem solving skills are needed to solve existing physics problems [13]. Creative thinking skills in motion dynamics material are needed through activities that invite students to think using their creative thinking skills to understand the concept of motion dynamics [4].

The facts found in schools are still many teachers who use conventional learning. Where the teacher is the center of learning, so that it has an impact on the creative thinking skills of students because the ability to think is limited. The same thing also arises from research conducted by Ref [14] which states that teachers are more dominant in learning activities. In addition, based on research conducted by Ref [15], it can be seen that 63% of students' creative thinking skills are in the low category. Furthermore, based on the results of the interview, it can be seen that in the material of motion dynamics, teachers still rarely use the PjBL model integrated with STEM. Many lesson plans made by teachers on motion dynamics still use Problem Based Learning, guided inquiry, and discovery learning models.

This research aims to analyze how applying the PjBL model integrated with the STEM approach can influence and improve students' creative thinking abilities in motion dynamics material. Through this research, insight can be gained regarding the effectiveness of integrating STEM and PjBL in improving various indicators of students' creative thinking abilities, which can later be used as a reference for developing more innovative and effective physics learning methods.

II. Methods

This descriptive qualitative research uses a single case study research design. The stages of this research are plan, design, prepare, collect, analyze, and share. The research data were collected from observing creative thinking skills through the implementation of stem-integrated pjl. Data were also obtained from interviews with students after carrying out learning activities at the fourth meeting. In addition, data were obtained from students' worksheet documents. Data analysis in this study used interactive data analysis, which consists of 4 stages as follows [16].

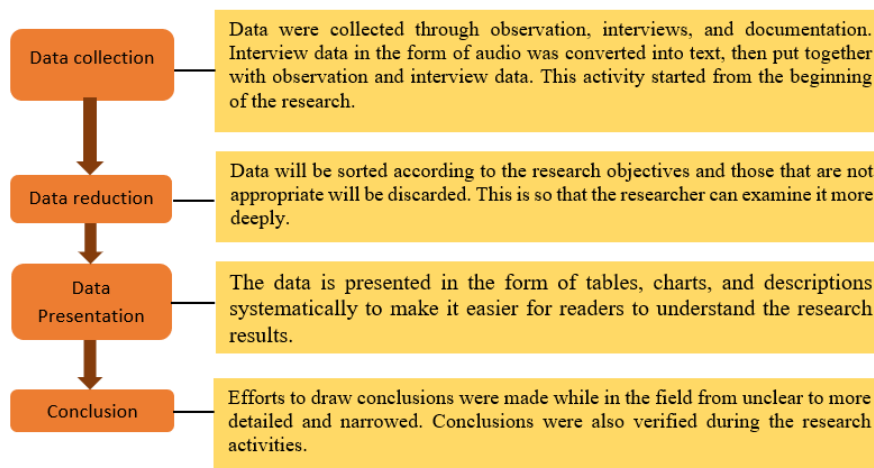


Figure 1. Research data analysis

III. Results and discussion

Results

This research was carried out at Rambipuji High School on class XI 2 students during the odd semester of the 2023/2024 academic year with physics learning material about motion dynamics. The number of participants was 33 students, who were then divided into six groups. Based on the results of research that have been conducted, students' creative thinking abilities based on student worksheets show that two indicators are in a good category, namely fluency and elaboration, while the other two indicators, flexibility and originality, are in a low category. The details are shown in Table 2.

Table 2. Work assessment data of group learners' worksheets

Indicators of Creative Thinking Skills	Frequency			
	Very Poor	Poor	Good	Very Good
Fluency	-	-	2	4
Flexibility	-	5	-	1
Originality	-	5	1	-
Elaboration	-	-	-	6

Apart from the students' worksheet in groups, the main data on creative thinking skills were also obtained based on the observation results in Table 3.

Table 3. Student observation data

Indicators of Creative Thinking Skills	Frequency			
	Very Poor	Poor	Good	Very Good
Fluency	-	5	19	9
Flexibility	-	22	8	3
Originality	-	21	9	3
Elaboration	-	1	17	15

The research results on each indicator can be described as follows.

a. Fluency

In the fluency indicator based on students' worksheet, it shows that 2 groups are in the good category and 4 groups are in the excellent category. It can also be seen from the observation results which show that 5 students are in the less category, 19 students are in the good category, and 9 students are in the excellent category. The following is an excerpt of the student discussion:

“The cause of accidents is usually caused by tire slip factors with asphalt, using seat belts so that when braking does not get out of the vehicle, and the car must use lightweight materials so that the mass of the car is small and able to produce high speed” (Discussion, K2, AP).

Students' worksheets on the fluency indicator are as shown in Figure 2.

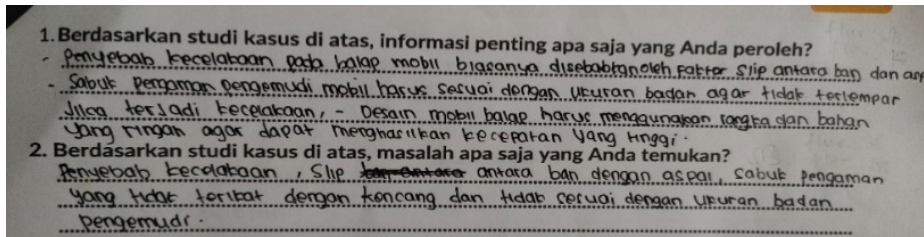


Figure 2. Students' Worksheet Fluency Indicator Very Good Category

The picture above is an example of an answer in the excellent category because it can mention lot of important information and problems contained in the case study. This is also supported by the results of student interviews as follows.

“Yes can find important information from the case study” (Interview, K1-6,SN)

b. Flexibility

The flexibility indicator based on students' worksheet shows that 5 groups are in the poor category and 1 group is in the very good category. It can also be seen from the observation results which show that 22 students are in the less category, 8 students are in the good category, and 3 students are in the excellent category. The following is an example of a student discussion excerpt:

“The technology is through the concept of motion dynamics to make a toy car” (Discussion, K3,AC)

Students' worksheet on the flexibility indicator as shown in Figure 3.

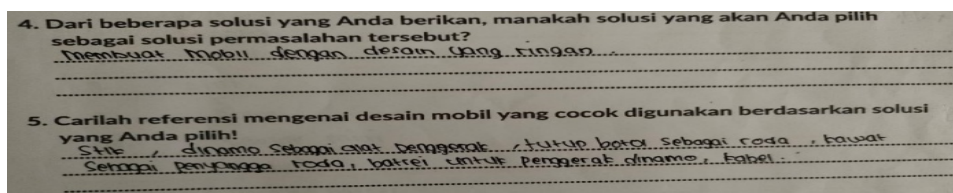


Figure 3. Students' Worksheet on the Flexibility Indicator in the Less Category

The picture above shows student work in the less category because it has not been able to provide varied answers. This is also supported by the results of the interview as follows.

“The seat belt must fit the body because when there is a collision the driver does not get out and does not bounce off” (Interview, K1, DA)

c. Originality

In the originality indicator based on students' worksheet, it shows that 5 groups are in the poor category and 1 group is in the good category. It can also be seen from the observation results which show that 21 students

are in the less category, 9 students are in the good category, and 3 students are in the excellent category. The following is an example of a student discussion excerpt:

“...this I design according to the reference” (Discussion, K3, RS)

Students’ worksheet on the originality indicator as shown in Figure 4.

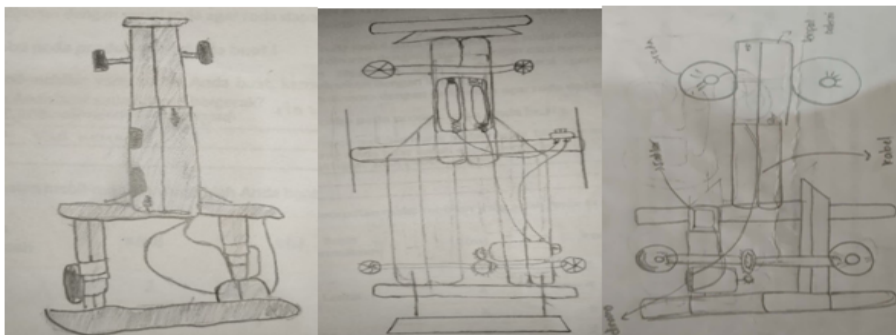


Figure 4. Students’ Worksheet of Originality Indicator of Lack Category

The picture above is included in the deficient category because students cannot create designs based on the results of their own thinking. This is also supported by data from student interviews as follows.

“From our group there is no additional innovation” (Interview, K2, AP)

d. Elaboration

In the elaboration indicator based on students' worksheet, it shows that 6 groups are in the excellent category. This can also be seen from the observation results which show that 1 student is in the less category, 17 students are in the good category, and 15 students are in the excellent category. The following is an example of a student discussion excerpt:

“The link with the toy cars is that if the mass is large, the speed of the toy cars will be slow, otherwise if the toy cars have a small mass, the toy cars will move quickly. The toy cars that we made moved slowly probably because the materials we made were not appropriate” (Discussion, K5, ZN)

Student work on the elaboration indicator as shown in Figure 5.

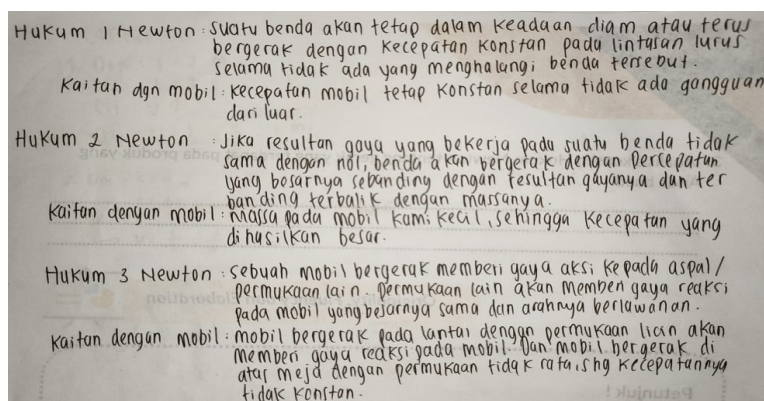


Figure 5. Students’ Worksheet on Elaboration Indicator Very Good Category

The picture above shows an example of students’ worksheet that is included in the excellent category because it can develop and detail ideas. This is also supported by the data from student interviews as follows.

"Yes, I was directly involved in the project activities" (Interview, K1-6, SN).

Discussion

Based on the results of the research that has been done, the results show that 2 indicators are in the good category and two indicators are in the less category. Indicators of creative thinking skills that are in the good category are fluency and elaboration. Furthermore, those in the less category are flexibility and originality.

a. Fluency

The results showed that the creative thinking skills indicator for fluency was in the good category because in several activities carried out, students were good at providing many ideas and answers. When answering the triggering questions given by the teacher, students gave more than one answer to the same question. The following is an excerpt when students answer the lighter question.

"The size of the racing car is small because if it is big, it is objectionable" (K6, MF)

"Because if the size is small the speed is faster" (K3, FA)

In addition, when answering questions on students' worksheet related to case studies, students can mention important information, problems, and solutions with many answers. Furthermore, the fluency indicator also appeared when students answered the teacher's questions when making presentations. Students can mention the obstacles and innovations given with many answers. The following is an excerpt when students answer the teacher's question regarding the innovation given.

"Making a design that is different from the example given, namely by providing a side body, so that when driving it can avoid direct collisions. Then we made the wheels of the car from 2 bottle caps so that it can move straight" (K4, NY).

The activities that have been carried out by these students are in accordance with what is revealed by Ref. [17] that students are said to have creative thinking skills if they can provide many ideas or answers. This is also in line with research conducted by Ref [18] that students are said to have fluency indicators when they can provide a variety of answers that are relevant to the problems given. Therefore, when given a problem students can provide a variety of solutions that are in accordance with the problem.

b. Flexibility

The results showed that the indicator of creative thinking skills for flexibility was in the deficient category because in some activities, students were less able to provide different or varied answers or only use one perception. First, when students only associate STEM components using 1 perception. Furthermore, when answering questions on case studies. In general, the majority of groups did not provide varied answers when choosing solutions. However, there were groups that gave varied answers with several perceptions. Furthermore, the flexibility indicator appears when students mention the tools and materials used. In general, all groups are in the excellent category because they can mention tools and materials that vary according to the needs of the products they will make.

When viewed from some of these student activities, in general the majority of groups are less able to provide different or varied answers by using multiple perceptions. This is in line with research conducted by Ref [19] which states that the flexibility indicator is in the poor category because students do not have many thinking patterns and contradicts research conducted by Ref [17] which states that students are said to have flexibility indicators if students can provide diverse answers, but use different directions of thought or ways.

c. Originality

The results showed that the indicator of creative thinking skills for originality was in the deficient category because in several activities, students were less able to provide unique ideas and answers. The first is when designing and making products. Students tend to design and make products similar to the examples given by the teacher. In addition, based on the results of the study, it can also be seen that there are groups that have differences between the results of the design and the products that have been made. The originality indicator appears when students provide innovations to the products they make. There are several groups that provide

innovations in the products they make. The innovations given include giving color to the toy car products made, putting the dynamo in a different position, adding rubber to the battery compartment, making wheels from different materials, and adding side bodies to maintain shape during impact. However, when viewed from the design and shape of the toy cars, the products made by the majority of the groups were the same as the examples given.

This is in line with research conducted by Ref [18] that students have not been able to provide different ideas or answers because most students provide ideas or answers based on what they have seen and contrary to the statement of Ref [20] that students are said to have good originality indicators if they can compose something new or unique. The low skill of students in making something unique from the results of their own thinking will have an impact on the low ability of students to solve a problem [18].

d. Elaboration

The results showed that the indicators of creative thinking skills for elaboration were in the good category. This is because in the learning process, students are good at developing ideas and detailing their ideas. The first activity that can bring out the elaboration indicator is when making products. In groups, students make products and discuss so as to find solutions to problems. The second activity that can bring out the elaboration indicator is product testing. When conducting product testing activities, students will record the travel time at a certain distance which will then be used to calculate the speed of the toy car that has been made. Furthermore, students are asked to analyze Newton's Law of motion in detail.

Some of these student activities are in line with research conducted by Ref [18] which states that students have an elaboration indicator if they can provide an idea in detail. Ref [17] also stated that students have elaboration indicators if they are able to solve problems using detailed steps. In addition, students are said to have good elaboration indicators if they can provide explanatory descriptions of their ideas or ideas in detail [19].

IV. Conclusions

Based on the research results that have been described, it is concluded that students' creative thinking skills through the implementation of the STEM-integrated PjBL Model on motion dynamics material are in the good category for fluency and elaboration indicators, and are in the less category for flexibility and originality indicators. The fluency indicator is in the good category because in some activities carried out, students are good at providing many ideas and answers. The flexibility indicator is in the less category because in some activities, students are less able to provide different or varied answers or only use one perception. The originality indicator is in the deficient category because in some activities, students are less able to provide unique ideas and answers. The elaboration indicator is in the good category because in the learning process, students are good at developing ideas and detailing their ideas.

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