



## Implementation of STEM Integrated Project Based Learning (PjBL) to Improve Problem Solving Skills

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### Abstract

The 4Cs are skills that emphasize learning across the 21<sup>st</sup> century (Critical thinking, Communication, Collaboration, Creativity). Problem-solving, one of the 21<sup>st</sup> century's skills, developed by implementing PjBL-STEM learning models. PjBL-STEM learning focuses on developing students' ability to be more engaged, innovative, and open to the idea of concepts learnt through project-based activities that incorporate STEM aspects in real life. The study's goal is to examine how PjBL-STEM learning improves problem-solving skills. The research method used was quantitative research through a one-group pre-experimental design with pretest and posttest. A total of 35 students from class XI IPA 2, SMA X Muhammadiyah Surabaya, participated in the study. This study uses purposive sampling to consider students' abilities and conditions of delivery of subject matter. The study's results (N-gain) were 0.59, classified as "medium". According to the findings of this study, Learning the PjBL-STEM model has been sufficient for enhancing problem-solving abilities in dynamic fluid materials. The characteristics of the PjBL-STEM learning model that focuses on the 'student-centred model' significantly influence problem-solving skills. The advantages of this model should be accompanied by improvement of educational facilities and teaching skills in the learning process in order to create a balanced learning environment

**Keywords:** 21<sup>st</sup> century learning; PjBL-STEM; Problem-Solving Skill

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### INTRODUCTION

Education is a critical factor in the 21<sup>st</sup> century. Learners are encouraged to master a wide range of skills relating to the four components of living, which include learning to understand, do something, become, and live in a society in the 21st century (Jayadi et al., 2020). In fact, not all schools can apply the paradigm. 21<sup>st</sup>-century learning. The results of studies conducted on learning that occur in schools today still tend to be

passive, and the activities are still centred on teachers (Samudra et al., 2014).

Research on five high schools in Malang city revealed that physics learning could not invite students to be actively involved in learning (Istyowati et al., 2017). Research conducted by (Fitriyah, 2017) revealed that physics learning at one of MAN Mojokerto, Mojokerto, still uses lecture methods so that students are less actively involved. Learning today still describes teacher-



active and student-passive (Ahdinirwanto et al., 2013). In general, the school applies the method of lectures in the learning process. This often makes students less actively involved in learning. Teachers are considered to manage to learn effectively, which includes selecting appropriate learning strategies and models according to the material to be taught. The selection of this strategy aims to spur ability and increase students' learning interest so that learning goals can be achieved (Minsih & D, 2018). Physics learning is complex learning that requires various skills in its mastery, such as problem-solving skills. According to (Herawaty et al., 2018), problem-solving skills play an important role in influencing students to be more confident in various contexts of problems, helping students learn their facts, concepts, principles, and realizations. The process prioritizes the strategic steps taken by students in achieving problem-solving.

Physics investigates the interactions of the universe in numerous forms. symptoms that can train the ability to think and reason (Supardi et al., 2012). Physics learning is a crucial lesson to train thinking and problem-solving skills in everyday life (Chodijah et al., 2012) Physics is a fundamental science in applied science. Physics contains theories that need to be understood and applied in learning to train student problem-solving skills (Pratiwi & Wasis, 2013).

The physics learning process should be specifically designed to train and develop students' abilities. According to Piaget, knowledge will be meaningful when students discover their knowledge. Knowledge can be obtained when students do physical activities (hands-on activity) where they can increase their creativity to develop an idea or ideas. The learning process in the classroom should be student-oriented. The teacher acts as a

facilitator who helps students give directions so that there is no misconception.

Project-Based Learning (PjBL) was established as a learning method that encourages students to develop their knowledge and demonstrate understanding achieved through the numerous representations (Kurniawan et al., 2018). PjBL provides meaningful experiences and produces a project in the learning process (Afriana et al., 2016). PjBL is innovative learning to train student's knowledge collaboratively in making projects and proficiency in using technology to solve the problem (Astuti et al., 2019) PjBL is a student-centred learning model that enables students to prepare learning process, collaborate with peers, and develop creative products that can be presented (Fisher et al., 2020). PjBL engaged student-centred, represented by constructive investigations, collaboration, communication, and reflection in actual practices (Kokotsaki et al., 2016).

PjBL learning has the following characteristics, 1) Students plan frameworks. 2) There are problems that students will solve. 3) Students determine problem-solving solutions. 4) Students work collaboratively in managing problem-solving information. 5) The process of evaluation and reflection periodically. 6) The final product will be qualitatively evaluated. 7) The learning process is very tolerant of mistakes and changes. (Jauhariyyah, Suwono, 2017).

PjBL is an innovative learning model that trains problem-solving skills in real-life situations, consistent with the development of students' soft skills (Vogler et al., 2018). The PjBL learning model includes a complex set of learnings that help students to master a wide range of 21<sup>st</sup> century or 4C skills. (Dewi et al., 2017). The relationship between PjBL learning methods & 21<sup>st</sup> century skills is listed in Table 1.

Table 1 Correlation between PjBL learning method & 21<sup>st</sup>-century skills

|             | <b>Skills of the 21<sup>st</sup> century</b>                                       |                                                       |                                                              |                                               |
|-------------|------------------------------------------------------------------------------------|-------------------------------------------------------|--------------------------------------------------------------|-----------------------------------------------|
|             | <b>Digital literacy</b>                                                            | <b>Ingenious Thinking</b>                             | <b>Effective communication</b>                               | <b>High productivity</b>                      |
| <b>PjBL</b> | Applying cognitive-based advanced technologies as well as communication strategies | Driving questions inspire students' original thinking | Communication which been defined by a thorough investigation | Produce and display project-related products. |

Adapted from (Mc. Grath, 2004)

STEM is frequently associated with project-based learning since STEM is a method for structuring a project (Samsudin et al., 2018). The incorporation of stem approaches can train 21<sup>st</sup>-century skills such as collaboration, creativity, critical thinking, and communication, also known as the 4Cs (Amelia & Santoso, 2021; Hakim et al., 2019; Musa et al., 2012)

STEM, which stands for Science, Technology, Engineering, and Mathematics, was founded by NSF USA in 1990. It provides knowledge to learners about the laws and concepts that apply in nature; Technology is an artificial tool that facilitates work; Engineering is the knowledge to operate or design a procedure that solves a problem; Mathematics is a science that combines quantities, numbers, and space that requires only logical arguments without or accompanied by empirical evidence (Mulyani, 2019). STEM is a bridge that connects educational institutions with the real world. A learning approach that can guide students through research, discussion, collaboration, and critical thinking. This learning defines the process of applied work in a real-world context, as then students can analyze and implement knowledge applicability in STEM fields (Khalil & Osman, 2017; Rachmayati et al., 2020). STEM is concerned with authentic practices that can increase students' learning interest (Lou et al., 2014).

Learning with STEM is contextual learning where students will understand the problems around them. So that students will feel more curious and learn to understand what happened its causes, and its effects and strive to find a solution (Schmidt et al., 2020).

According to (Jolly, 2014) STEM has six specific characteristics: Teaching focuses on real-world problems and finding solutions to those problems, STEM lessons are guided by engineering design processes derived from student thinking, and productive teamwork, open learning activities but still have limitations, integrating mathematics and science so that students know the applications of both lessons, offering a variety of creative solutions to share problems. Students are supposed to have problem-solving skills in the context of their order to be prepared for the challenges of the 21st century in order to compete globally (Goddess et al., 2017).

In applying the 2013 curriculum, the PjBL learning model is recommended because it can provide real experience at the time of learning, while STEM is a learning approach (Jauhariyyah, Suwono, 2017). Characteristics of PjBL and STEM emphasize the design process with a systematic approach to solving problems. (Han et al., 2016).

Several studies on PjBL-STEM have been conducted by researchers, including (Simeon et al., 2022), using the PjBL-STEM learning model to improve

students' self-efficacy. Student self-efficacy plays a role in future job opportunities. PjBL-STEM can train students' critical thinking skills; a review of critical thinking skills in experimental classes increases likelihood and uncertainty indicators (Parno et al., 2022). In addition, PjBL-STEM can train students' scientific reasoning by emphasizing various possible solutions to design projects (Koes-H & Putri, 2021). This study used the PjBL-STEM model to improve problem-solving capabilities in dynamic fluid materials.

### METHOD

This research aimed to examine the use of PjBL-STEM learning model on the problem-solving abilities of grade XI high school students on dynamic fluid materials. Use quantitative research with pre-experimental design experiments. This method was selected to determine the difference in the level of problem-solving ability in students who were given learning using PjBL-STEM. The research steps carried out are listed in Figure 1.

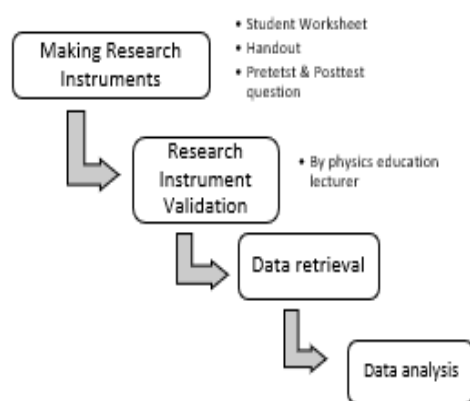


Figure 1 Research Flowchart

The PjBL-STEM learning steps according to Laboy-Rush are listed in Table 2.

Table 2 PjBL-STEM learning steps according to Laboy-Rush

| Stages        | Description                                                                                                  |
|---------------|--------------------------------------------------------------------------------------------------------------|
| Reflection    | Guide students into the context of problems so that students can understand and get ideas to solve problems. |
| Research      | Provide learning by developing discussions that can complicate students' understanding of solving problems.  |
| Discovery     | Form groups of students to process information and present problem-solving solutions.                        |
| Application   | Testing the products that have been made, students connect aspects of STEM in this stage.                    |
| Communication | Presents project results to develop communication skills in problem-solving.                                 |

The research design used one group pretest-posttest design is listed in Table 3.

Table 3 One group pretest-posttest design

| Pretest | Treatment | Posttest |
|---------|-----------|----------|
| $Z_1$   | Y         | $Z_2$    |

Description:

$Z_1$ : pretest value

Y: learning with the PjBL-STEM model

$Z_2$ : posttest value

Learning with stem integrated PjBL models influences students' problem-solving skills ( $Z_2 - Z_1$ ).

The initial stages of this research include preparing research instruments in the form of problem-solving skills tests (pretest and posttest) and student worksheets. An instrumented test in the context of an eight-question overview is used to assess students' problem-solving abilities. Each problem contains the stages of problem-solving, according to Heller.

The problem solving stages used in this study are listed in Table 4.

Table 4 The stages of problem solving according (Heller & Heller, 2010).

| Problem-solving stages         | Description                                                                                                                                             |
|--------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------|
| Focus on the problem           | visualize a situation or event by sketching a drawing, stating the question according to the problem, identifying useful approaches to reach a solution |
| Description of the problem     | Identifying the ways of problem-solving                                                                                                                 |
| Plan a solution to the problem | Outline problems, such as looking for related variable relationships.                                                                                   |
| Executing a plan               | Follow the outline of a previously made plan                                                                                                            |
| Evaluating solutions           | Compatibility between solutions and problems                                                                                                            |

The process of data retrieval includes observation to determine the condition of the sample, determining the number of samples, offering a pretest to determine the initial capabilities of student problem-solving skills on the material dynamic fluid, evaluation and treatment of learning with the PjBL-STEM model for three meetings, and the provision of posttest to find out the improvement of problem-solving skills after given treatment. The research was conducted at Muhammadiyah X High School, Surabaya. Sampling by purposive

sampling technique with as many research samples as 35 students from grade XII IPA 2. Analysis of Problem-solving Skills improvement can be analyzed using N-gain formula and the criteria used are listed in Table 5.

$$<g> = \frac{S_f}{S_m - S_i} \dots \dots (1)$$

Description:

<g>: N-gain

S<sub>i</sub>: Pretest value

S<sub>f</sub>: Posttest value

S<sub>i</sub>: Maximum score

Table 5 N-Gain criteria

| N-Gain Score      | Criterion N-Gain |
|-------------------|------------------|
| 0.70 < <g> :      | High             |
| 0.30 ≤ <g> ≤ 0.70 | Medium           |
| <g> < 0.30        | Low              |

(Wijayanto et al., 2020)

## RESULT AND DISCUSSION

Research data is in the form of pretest and posttest scores to demonstrate an improvement in problem-solving abilities (shown in Table 6). Improved problem-solving skills are analyzed through the N-gain score criteria. As for the criteria for improving learning outcomes using N-gain scores (in Table 7).

Table 6 Pre and posttest results

|               | Pretest | Posttest |
|---------------|---------|----------|
| Average value | 69.94   | 87.80    |
| Highest value | 77.00   | 94.00    |
| Lowest value  | 60.00   | 82.00    |

Table 7 Criteria for N-gain score of research results

| N-gain | Criterion |
|--------|-----------|
| 0.59   | Medium    |

Pretest and posttest results in the experimental class showed significant changes. Pretest results were at least 60.00, and highs were 77.00 with an average of 69.94; however, after being

treated in the form of physical learning using the PjBL-STEM model, there was an improvement in problem-solving skills. The average posttest result is 87.80, the lowest for posttest is 82.00, and the highest is 94.00.

Table 6, shows improvements in problem-solving skills with moderate categories. According to the findings of this research, learning with PjBL-STEM is effective enough to improve problem-solving skills in dynamic fluid materials. The study results (N-gain) showed the number 0.59 and categorized as "medium". Several factors affected, including the type of research instruments In the form of structured questions. The disadvantage of this type is that students must be able to answer the initial questions in order to be able to do other questions. (Apriyani et al., 2019). Attitude toward the learning process and self-efficacy plays important roles in students problem-solving skill (Öztürk et al., 2020)

During learning with the PjBL-STEM model, students are assigned contextually in the form of making a product (household water flow plan) by linking STEM aspects that are in line with the dynamic fluid concept. In addition, students are also required to present products that have been made. In this stage, students can demonstrate the ability to communicate and apply conceptual understanding to practice a problem-solving skill (Ince, 2018). However, this is only done by a few groups. The teacher is in charge of evaluating the solution to the problem, whether it is appropriate or not. Since the presentation of the results is only done by a few groups, this can cause a lack of maximum student problem-solving ability.

In line with (Yuliana et al., 2020), physics learning using the PjBL-STEM model can improve problem-solving skills in electromagnet induction materials with the acquisition of N-gain

in experimental class and control class 0.50 and 0.31, in contrast. STEM approaches can train problem-solving skills better when compared to classes with conventional learning (Parno et al., 2019).

Learning with the PjBL-STEM model invites students to learn from contextual problems and look for a project-based solution. Integrating science, technology, engineering, and mathematics concepts to design and create group projects. Students learn to collaborate, communicate, and share knowledge relevant to the project (Arifin Baihaqi et al., 2020; Widyasmah et al., 2020). PjBL-STEM can provide a valuable experience in learning because students are actively involved in learning, thereby increasing learning motivation (Shin, 2018).

## CONCLUSION

According to the study's findings, the PjBL-STEM learning system can enhance problem-solving abilities. The increase is reflected in an N-gain value of 0.59, also classified as "medium". There is an improvement in students' cognitive abilities because PjBL-STEM is a constructivist learning model that emphasizes the process of problem identification to produce solutions in the form of contextual products by linking STEM aspects.

The findings of this study can be used as a starting point for future research on the application of PjBL-STEM learning models. Noting the positive impact of PjBL-STEM learning, suggestions for further research can relate to other 21<sup>st</sup> century skills (4Cs) and applying PjBL-STEM models in education and other subjects.

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