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Application of STEM-PBL Learning to Improve Students' Higher-Order Thinking Skills in Rotational Dynamics Topic

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ABSTRACT

This research aims to determine the effectiveness of applying STEM-PBL learning to improve higher-order thinking skills in rotational dynamics topics. This research is included in the quasi-experimental design research with a nonequivalent control group design. The test instrument used in this research was a test of higher-order thinking skills which refers to the cognitive level of the revised Bloom's Taxonomy. Based on the results, the n-gain value in the experimental class in the C4 indicator was 0,70, C5 was 0,54, and C6 was 0,57. Meanwhile, in the control class, the C4 indicator was 0,27, C5 was 0,43, and C6 was 0,36. The effectiveness of STEM-PBL learning to improve higher-order thinking skills was obtained from the effect size value and obtained a value of 0.875 in the high category. According to the findings, STEM-PBL learning is effective in improving high-level thinking skills in rotational dynamics material.

Keywords: **STEM-PBL Learning; Higher-Order Thinking Skills; Rotational Dynamics**

ABSTRAK

Penelitian ini bertujuan untuk mengetahui efektivitas penerapan pembelajaran STEM-PBL untuk meningkatkan keterampilan berpikir tingkat tinggi pada materi dinamika rotasi. Penelitian ini termasuk dalam jenis penelitian quasi eksperimen dengan rancangan nonequivalent control group design. Instrumen tes yang digunakan dalam penelitian ini adalah tes keterampilan berpikir tingkat tinggi yang mengacu pada taraf kognitif Taksonomi Bloom yang telah direvisi. Berdasarkan hasil penelitian, nilai n-gain pada kelas eksperimen pada indikator C4 sebesar 0,70, C5 sebesar 0,54, dan C6 sebesar 0,57. Sedangkan pada kelas kontrol pada indikator C4 sebesar 0,27, C5 sebesar 0,43, dan C6 sebesar 0,36. Efektivitas pembelajaran STEM-PBL untuk meningkatkan keterampilan berpikir tingkat tinggi diperoleh dari nilai effect size dan memperoleh nilai sebesar 0,875 dengan kategori tinggi. Berdasarkan hasil penelitian, pembelajaran STEM-PBL efektif untuk meningkatkan keterampilan berpikir tingkat tinggi pada materi dinamika rotasi.

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Kata Kunci: **Pembelajaran STEM-PBL; Keterampilan Berpikir Tingkat Tinggi; Dinamika Rotasi**

PENDAHULUAN

Possessing 21st-century skills is essential for students to be competent in contemporary advancements. 21st-century skills known as 4C include creative thinking skills, critical thinking, communication, and collaboration. One way that can be done to develop students' potential 21st-century skills is by applying these skills to a learning process that asserts higher-order thinking skills. Higher-order thinking skills (HOTS) are critical and creative thinking skills in solving problems [1]. HOTS can encourage students to think broadly and deeply about understanding the subject [2]. Therefore, HOTS is important in the learning process, improving performance and unraveling students' problems. In reality, Indonesian students' HOTS are still low [3]. This is shown by the results of TIMSS 2015 and PISA 2018 which state that the HOTS of students in Indonesia are still below average. [4].

One of the physics concepts that has many roles and applications in everyday life is rotational dynamics. However, students often find difficulty in solving HOTS questions in this material. This is shown by the results of Amalia's research [5] that 63.75% of students experienced visualizing problems, 21.25% of students had difficulty describing problems, 58.75% of students experienced difficulty in planning solutions to solve problems, 71.25% of students have difficulty in carrying out problem-solving solution plans and 78.75% of students have difficulty in checking and evaluating the results of problem-solving. Apart from that, several errors are often found by students in solving rotational dynamics problems, such as not being careful in reading the questions, not understanding questions that have pictures, not understanding the meaning of the distance between particles and the axis, students not knowing the equations that will be used for the solution. questions, not understanding the equations used, students not being careful in carrying out calculations, and students not knowing the units of physical quantities [6]. Apart from that, the cause of students' low HOTS is learning that is still observed and is still in the form of memorizing concepts [7]. Low HOTS can also be caused by less than optimal use of learning models, methods, and approaches, as well as the ability of teacher-centered learning [8].

One effort that can be made to improve HOTS is by applying methods and approaches that can construct students' understanding and create meaningful learning. The STEM approach can make students better at solving problems, discovering new things, being independent, thinking logically, thinking critically, creatively, and scientifically, as well as being technologically literate [9], [10]. Venalia's research results reveal that the implementation of the STEM approach in learning is effective in raising students' cognitive learning outcomes [11]. Meanwhile, Alatas's research states that the STEM approach is effective in improving problem-solving skills [12]. Learning science with STEM makes students understand science better than usual [13]. STEM learning is very necessary because it has the potential to increase students' HOTS [14].

To increase students' HOTS, STEM learning can be combined with other learning models, one of which is the problem-based learning (PBL) model. STEM-PBL learning is not only able to enhance critical thinking skills but can also improve scientific literacy skills and character, as well as students' cognitive learning outcomes [15], [16]. Integrating STEM-PBL learning in studying has the potential to provide opportunities for students to apply HOTS to solve daily life problems that are resolved through STEM literacy. In this research, STEM-PBL learning is applied to increase students' HOTS on the concept of rotational dynamics. This research aims to 1) compare the increase in HOTS by implementing STEM-PBL learning and conventional learning, and 2) the effectiveness of STEM-PBL learning on students' HOTS.

METHOD

This research employs a quasi-experimental design using a nonequivalent control group design [17], which allowed us to see the difference in students' HOTS before and after learning about rotation dynamics topics. The population in this research consisted of 136 students in class 11^{th}-grade science class SMA Negeri 1 Sambas for the 2023/2024 academic year. The number of samples in this research was 64 students from class 11^{th}-grade science class who were selected using the intact group random sampling technique.

This research uses two classes where contain an experimental class and a control class with each class of 32 people. In both experimental and control groups, a set of lessons about rotational dynamics was implemented, but with different learning. In experimental class, learning is carried out using STEM-PBL learning which students student-centered. Another class is the control class, where learning is carried out using traditional learning with teacher-centered.

This research has three stages of implementation. 1) Before commencing the learning processes, both the experimental class and the control class underwent a pretest. 2) Following the pretest, the experimental class received treatment through the application of STEM-PBL learning during the learning processes, while the control class adhered to conventional learning, 3) Upon completing the learning processes, at the end of the learning experimental class and control class students were given a posttest which aimed to find out the results of improving student's HOTS.

The methodology employed for data collection in this study involves utilizing measurement techniques through essay tests focused on rotation dynamics topics. The purpose of using the

HOTS test is to assess the attainment of indicators of HOTS. The aspects assessed refer to indicators of the Revised Bloom's taxonomy of HOTS, namely: (1) Analyzing, (2) Evaluating, and (3) Creating [18].

Following the collection of data, an analysis is conducted to assess the growth of students' HOTS. However, before the data was analyzed, a normality test was conducted to examine the data distribution. The normality test used in this research was the Kolmogorov-Smirnov normality test and it was found that the data for both classes had a normal distribution.

Once the data's underlying distribution was established, a parametric statistical test was conducted. The purpose of this test was to precisely identify whether the observed variations between the experimental group and the control group were statistically significant, meaning they were unlikely due to random chance. Independent t-test was used in this research which aims to carry out statistical tests, this test uses IBM Statistic 27.0 software. To find out further differences in HOTS improvement, an n-gain test was carried out. Calculation of the n-gain value uses the following formula.

$$g = \frac{X_{Post} - X_{Pre}}{X_{max} - X_{pre}} \tag{1}$$

Detail:

g : gain value

X_{Post} : posttest score

X_{pre} : pretest score

X_{max} : maximum score

Following the completion of calculations, the n-gain value was determined. The value was then interpreted based on the n-gain value category, which is shown in Table 1 [19].

Table 1. N-gain value category

N-gain Value	Category
g > 0,7	High
0,3 ≤ g ≤ 0,7	Medium

g < 0,3	Low

The effectiveness of applying STEM-PBL learning to improve HOTS uses Cohen's d effect size. After the calculations were carried out and the Cohen's d effect size value was obtained, the value was then interpreted based on Table 2 [20].

Table 2. Effect Size Category

Category	***Effect Size***
Very Low	0 ≤ d ≤ 0,2
Low	0,2 ≤ d ≤ 0,5
Currently	0,5 ≤ d ≤ 0,8
High	0,8 ≤ d ≤ 1,0
Very High	d ≥ 1,0

RESULTS AND DISCUSSIONS

The results of an increase in HOTS and the effectiveness of STEM-PBL learning were gauged through pretest-posttest data and effect size measurement. The outcomes of both result tests are presented in score format. Students are given a pretest before being given treatment to determine the level of students initial HOTS. After being given treatment, a posttest is given to students to determine the student’s final HOTS level. Table 2 illustrates the pretest results for both the experimental class and the control class.

Table 2. Distribution of Preset Data for Experiment Class and Control Class

Data Distribution	**Experiment Class**	**Control Class**
Mean	16,25	13,31
Maximum Score	27	37
Minimum Score	7	1
Standard Deviation	131,37	121,39

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Based on Table 1, 16,25 was average in the experimental class from the pretest outcomes, while the pretest outcomes in the control class were 13.31. The average pretest outcomes indicate that the experimental class surpasses the control class in size. Consequently, there is no notable distinction between the results in both classes. This suggests that the experimental class and control class possess similar initial skills. The pretest results for both classes show that the students' HOTS skills before being given treatment were still low. After the treatment, a posttest was administered to both classes to observe the ultimate outcomes of the student's HOTS. The posttest results are shown in Table 3.

Table 3. Distribution of Posttest Data for Experiment Class and Control Class

Data Distribution	Experiment Class	Control Class
Mean	41,39	30,42
Maximum Score	57	57
Minimum Score	16	7
Standard Deviation	229,80	168,79

According to information in Table 3, it is shown that the outcomes of student's HOTS in the experimental class have an average of 41.39, and in the control class, the average is 30.42. Based on posttest results the average students' HOTS in the experimental class was exceeded than students in the control class. It means students' HOTS in the experimental class was higher than control class.

Statistical tests were carried out after the pretest and posttest data were obtained. However, before that, a normality test was conducted. The Kolmogorov-Smirnov normality test was used in this research and it helped by IBM SPSS Statistic 27.0 software. The outcomes of the pretest-posttest normality tests for both classes are detailed in Table 4.

Tabel 4. Normality Test Results

Kolmogorov-Smirnov		Sig
Experiment class	Pretest	0,200
	Posttest	0,200
Control class	Pretest	0,009
	Posttest	0,200

After the data was analyzed and the results obtained as in Table 4 showed that the significance value of the pretest and posttest data from both classes showed more than 0.05, so it could be concluded that both classes had a normal distribution. After obtaining the normality results of the pretest and posttest data, the hypothesis test was then conducted. The hypothesis test in this research uses parametric statistical tests using the IBM SPSS Statistics 27 software for independent t-tests. The outcomes of the pretest-posttest hypothesis tests are shown in Table 5 below.

Table 5. Hypothesis Test Results

	Pretest (Independent t-test)	**Posttest (Independent t-test)**
Sig. (2-tailed)	0,098	0,001
α	Sig. ≥ 0,05 = H_0 accepted	
Outcomes	H_0 accepted	H_a accepted

According to detail in Table 5, the outcomes of the posttest hypothesis indicate that the data significance value is less than 0.05, so Ha is accepted which states that there is a significant difference between the experimental class and the control class. The experimental class demonstrated a greater improvement in HOTS when compared with the control class. Therefore, STEM-PBL learning influences students' HOTS in rotational dynamics topics. This finding aligns with the research results by Nurazmi & Bancong and Alatas which revealed that STEM-PBL learning was able to improve critical thinking and problem-solving skills which are part of HOTS [12], [21]. The existence of a science, technology, engineering, and mathematics (STEM) approach in learning aids students to comprehend the material about inter-disciplines [19].

The increase in each indicator of HOTS in both classes was conducted from the n-gain value. The improvement in students' HOTS in both the classes for each indicator was illustrated in Figure 1.

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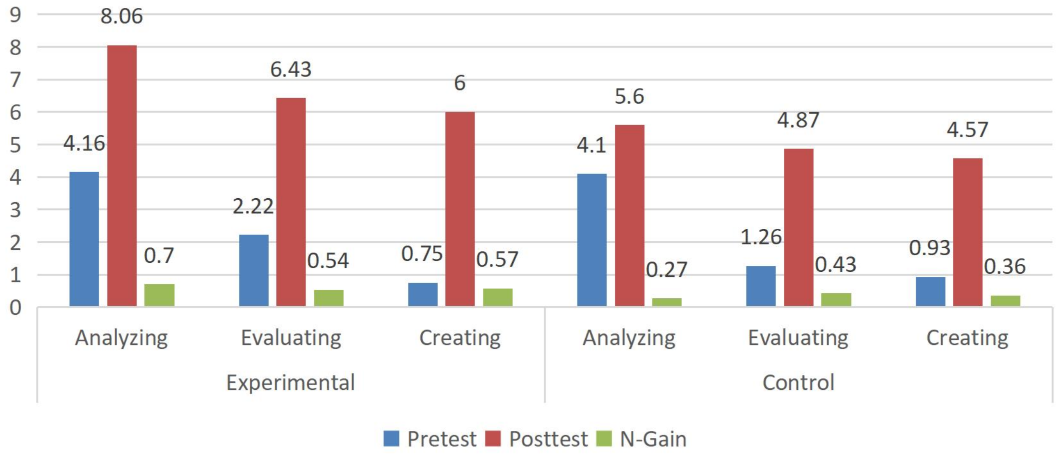

***Fig 1**. Graph of Improvement in HOTS for Experimental Class and Control Class*

According to information in Figure 1, the HOTS of both classes have increased in each indicator. The n-gain in the analyzing indicator (C4) in the experimental class was 0,70 and in the control class was 0,27. The increase in C4 in the experimental class was bigger than in the control class. The implementation of STEM-PBL can influence this indicator because STEM-PBL learning involves students actively during learning. The PBL model syntax facilitates students in practicing C4 indicators, namely problem-oriented syntax, where students are faced with contextual problems. In this syntax, the STEM aspects that occur are science and technology. In addition, the syntax guides individual and group investigations of students to explore relevant information, data, and facts based on the results of experiments and literature reviews. The STEM aspects of this syntax are science, technology, and mathematics. Apart from that, using student worksheets (LKPD) combined with STEM can facilitate students in developing HOTS. This is aligned with research results by Fithri and Munawaroh which reveal that STEM-based LKPD can improve students' critical thinking skills, where critical thinking skills are one component of higher-order thinking skills [22]-[24].

The n-gain value acquisition on the evaluating indicator (C5) in the experimental class was 0.54 and at the same time in the control class was 0.43. The significant increase in the C5 indicator was caused by learning that involved students directly in learning [25]. In implementing STEM-PBL learning, the syntax guides individual and group investigations, facilitating students to develop their skills in evaluating through searching for information and data that follows the results of experiments and literature reviews. In this syntax, the STEM aspects that occur are science, technology, and mathematics. Meanwhile, syntax analyzes and evaluates the problem-solving process, providing opportunities for students to evaluate a series of problem-solving processes. The STEM aspects implemented in this syntax are science and technology. Implementing STEM-PBL learning can train students in problem-solving, improving critical thinking skills and decision-making abilities [26]. In this way, HOTS can be trained and developed. Students with HOTS have creativity in solving problems and evaluating problem-solving strategies from another point of view.

The n-gain value on creating indicator (C6) in the experimental class was 0,57 and in the control class was 0,36. In implementation, the syntax of the PBL model is to develop and present work to facilitate students in developing thinking skills based on creating indicators. In this syntax, students are allowed to create their work as a series of problem solutions. This syntax applies to all aspects of STEM. However, the STEM aspect that stands out most in this syntax is engineering.

The experimental class experienced a greater increase, this was because, during the learning process that implemented STEM-PBL learning, it was indirectly able to train creative thinking skills which are one aspect of HOTS [24]. By training in creative thinking skills, students can become accustomed to solving problems by making solution steps to solve problems in various ways and from different points of view. The implementation of STEM-PBL learning can train students' creative thinking skills. This is aligned with research results by Koeswati and Yuniar which reveal that STEM-PBL learning influences and can develop students' creative thinking skills [27], [28].

According to the results obtained (based on Fig. 1), the HOTS of students in the experimental class and control class have improved. This indicates that learning activities that apply STEM-PBL learning can increase students' HOTS. The application of STEM-PBL learning in the experimental class is by applying all the syntax of the PBL model which is followed by aspects of the STEM approach in each syntax. Each PBL model syntax can train HOTS and the STEM approach can develop students' cognitive structures so that integrating the PBL model with the STEM approach has a positive impact on increasing students' HOTS [29].

Meanwhile, the HOTS of students in the control class also experienced an increase after being given treatment by applying the learning that is usually used, namely the lecture method. This increase was caused by the teacher explaining the solution to examples of HOTS questions related to rotational dynamics material during the learning process. This results in students being trained to develop HOTS based on problem-solving by answering the questions.

The HOTS of students in both classes improved after being given treatment. However, the enhancement in HOTS for the experimental class surpassed that observed in the control class. This indicates that HOTS in rotational dynamics material can be improved effectively through STEM-PBL learning. The effectiveness of STEM-PBL learning is determined based on the cohead’s d effect size value. The outcomes of computing Cohen’s d-effect size are presented in Table 6.

Table 6. Cohen's Effect Size Calculation Results

Independent Samples Effect Sizes

		Standardize	Point Estimate	95% Confidence Interval Lower	95% Confidence Interval Upper
Higher-order thinking skills result	Cohen's d	12.534	.875	.366	1.378
	Hedges' correction	12.683	.865	.362	1.362
	Glass's delta	12.877	.852	.321	1.372

Table 6 shows the effect size value and obtained a value of 0.875 in the high category. Considering the effect size values obtained, it can be inferred that the implementation of STEM-PBL learning was proven effective in enhancing HOTS in rotational dynamics topics. This finding aligns with the research results by Wahyuningtiyas, and Putra which state that STEM-PBL learning is effective in improving students' HOTS [30]. With STEM-PBL learning, students can practice skills in analyzing, evaluating, and creating in the process of finding solutions to problems that exist in everyday life related to rotational dynamics material, and can increase students' understanding of concepts. The result research by Cahyaningsih; Wulandari; and Putri revealed that STEM-PBL learning is effective in enhancing students' creative thinking skills, critical thinking, and cognitive learning outcomes [15], [16], [31].

CONCLUSION AND SUGGESTION

According to the research results, it can be concluded that (a) The increase of students' HOTS of experimental class on the indicators of analyzing (C4) was 0,70, evaluating (C5) was 0,54, and creating (C6) was 0,57. Meanwhile, the increase of students' HOTS control class on the indicators of analyzing (C4) was 0,27, evaluating was 0,43, and creating (C6) was 0,36. (b) The application of STEM-PBL learning is effective in improving students' HOTS in rotational dynamics material.

Some suggestions for future improvements based on research that has been conducted include (a) adding data collection instruments to observe and see students' responses in learning, (b) further research using STEM-PBL learning to expand the scope of research, not just limited in researching higher-order thinking skills but can also research scientific literacy or others.

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REFERENCES

[1] F. Eka Virdiyanti, B. Jatmiko Jurusan Fisika, and F. Matematika dan Ilmu Pengetahuan Alam, "Fezylia Eka Virdiyanti, Budi Jatmiko Learning Physics Pbl Model Using Contextual Approaches To Improve Student Higher Order Thinking Skills (HOTs)," vol. 09, no. 02, pp. 166–173, 2020.

[2] S. B. A. Ariansyah, Stepanus Sahala S., "Analisis kemampuan menyelesaikan soal HOTS fisika materi getaran harmonis di SMA Kristen Immanuel Pontianak," *J. Chem. Inf. Model.*, vol. 53, no. 9, pp. 1689–1699, 2019.

[3] I. Kusdianti, S. S. Sitompul, and D. Mahmuda, "Analisis kemampuan peserta didik dalam menyelesaikan soal HOTS kelas XI SMAN 2 Sungai Raya," *J. Pendidik. dan Pembelajaran Khatulistiwa*, vol. 8, no. 6, pp. 1–10, 2019.

[4] S. Hadi and Novaliyosi, "Trends in International Mathematics and Science Study (TIMSS)," *Pros. Semin. Call Pap.*, pp. 562–569, 2019.

[5] R. Amalia, S. S. Sitompul, and M. M. Syarif H., "Analisis Kesulitan Peserta Didik Dalam Penyelesaian Soal Hots Tentang Dinamika Rotasi Pada Kelas Xi," *J. Pendidik. dan Pembelajaran Khatulistiwa*, vol. 11, no. 2, pp. 1-8, 2022.

[6] A. Rajiman, T. Djudin, and E. Oktavianty, "Analisis Kesalahan Siswa Menyelesaikan Soal Dinamika Rotasi Berdasarkan Prosedur Newman Di Sma Negeri 7 Pontianak," *J. Pendidik. dan Pembelajaran Khatulistiwa*, vol. 11, no. 7, p. 705, 2022.

[7] S. Alfiah and D. Dwikoranto, "Penerapan Model Problem Based Learning Berbantuan Laboratorium Virtual PhET Untuk Meningkatkan HOTs Siswa SMA," *J. Penelit. Pembelajaran Fis.*, vol. 13, no. 1, pp. 9–18, 2022.

[8] E. Ludfianti, "Penerapan Model Problem Based Learning untuk Meningkatkan Hasil Belajar Peserta Didik pada Materi Elastisitas," *J. Pendidik. dan Pembelajaran Khatulistiwa*, vol. 2, p. 332, 2019.

[9] N. Baharin, N. Kamarudin, and U. K. A. Manaf, "Integrating STEM Education Approach in Enhancing Higher Order Thinking Skills," *Int. J. Acad. Res. Bus. Soc. Sci.*, vol. 8, no. 7, pp. 810–821, 2018.

Vol. 16 No 10 2025
Palagiarism Check 02/234/67/78
Prev DOI : 10.9644/sindoro.v3i9.252

[10] Parno, L. Yuliati, N. Munfaridah, M. Ali, F. U. N. Rosyidah, and N. Indrasari, "The effect of project based learning-STEM on problem solving skills for students in the topic of electromagnetic induction," *J. Phys. Conf. Ser.*, vol. 1521, no. 2, 2020.

[11] A. Venalia, T. Djudin, and E. Oktavianty, "Application of Project-Based Learning (PjBL) Models with STEM Approaches in Dynamic Electricity Material Learning," *Berk. Ilm. Pendidik. Fis.*, vol. 10, no. 3, p. 305, 2022.

[12] F. Alatas and N. A. Yakin, "The Effect of Science, Technology, Engineering, and Mathematics (STEM) Learning on Students' Problem Solving Skill," *JIPF (Jurnal Ilmu Pendidik. Fis.*, vol. 6, no. 1, p. 1, 2021.

[13] A. Permanasari, B. Rubini, and O. F. Nugroho, "STEM Education in Indonesia: Science Teachers' and Students' Perspectives," *J. Innov. Educ. Cult. Res.*, vol. 2, no. 1, pp. 7-16, 2021.

[14] Y. M. Heong, J. M. Yunos, W. Othman, R. Hassan, T. T. Kiong, and M. M. Mohamad, "The Needs Analysis of Learning Higher Order Thinking Skills for Generating Ideas," *Procedia - Soc. Behav. Sci.*, vol. 59, no. October, pp. 197–203, 2012.

[15] C. D. Putri, I. D. Pursitasari, and B. Rubini, "Problem Based Learning Terintegrasi STEM Di Era Pandemi Covid-19 Untuk Meningkatkan Keterampilan Berpikir Kritis Siswa," *J. IPA Pembelajaran IPA*, vol. 4, no. 2, pp. 193–204, 2020.

[16] F. Cahyaningsih and I. E. Roektiningroem, "Pengaruh Pembelajaran IPA Berbasis STEM-PBL Terhadap Keterampilan Berpikir Kritis Dan Hasil Belajar Kognitif," *E-Journal Pendidik. IPA*, vol. 7, no. 5, pp. 239–244, 2018.

[17] Sugiyono and M. E. Puspandhani, *Metode Penelitian Kesehatan*, 1st ed. Bandung: Alfabeta, 2020.

[18] L. W. Anderson *et al.*, *Taxonomy for_ Assessing a Revision 0F Bl00M'S Tax0N0My 0F Educati0Nal Objectives*. 2001.

[19] A. Saefullah, A. Suherman, R. T. Utami, G. Antarnusa, D. A. Rostikawati, and R. Zidny, "Implementation of PjBL-STEM to Improve Students' Creative Thinking Skills On Static Fluid Topic," *JIPF (Jurnal Ilmu Pendidik. Fis.*, vol. 6, no. 2, p. 149, 2021.

[20] L. Cohen, L. Manion, and K. Morrison, *Research Methods in Education*, 7th ed. London: Routledge, 2011.

[21] Nurazmi and H. Bancong, "Integrated STEM-Problem Based Learning Model: Its Effect on Students' Critical Thinking," *Kasuari Phys. Educ. J.*, vol. 4, no. 2, pp. 70–77, 2021.

[22] S. Fithri, A. U. Tenri Pada, W. Artika, C. Nurmaliah, and H. Hasanuddin, "Implementasi LKPD Berbasis STEM untuk Meningkatkan Keterampilan Berpikir Kritis Peserta Didik," *J. Pendidik. Sains Indones.*, vol. 9, no. 4, pp. 555–564, 2021.

[23] F. Munawaroh, R. D. Handayani, and B. Supriadi, "Implementasi Lkpd Berbasis Stem Untuk Mengukur Keterampilan Berpikir Kritis Pada Pokok Bahasan Gerak Lurus," *J.*

Pembelajaran Fis., vol. 12, no. 1, p. 9, 2023.

[24] U. Rosidin, A. Suyatna, and A. Abdurrahman, “A combined HOTS-based assessment/STEM learning model to improve secondary students’ thinking skills: A development and evaluation study,” *J. Educ. Gift. Young Sci.*, vol. 7, no. 3, pp. 435–448, 2019.

[25] A. Fitriyani, T. Toto, and E. Erlin, “Implementasi Model Pjbl-Stem Untuk Meningkatkan Keterampilan Berpikir Tingkat Tinggi,” *Bioed J. Pendidik. Biol.*, vol. 8, no. 2, p. 1, 2020.

[26] H. Nisa, M. Junus, and L. Komariyah, “Penerapan Model Problem Based Learning Berbantuan Simulasi PhET Berbasis Instrumen HOTS Terhadap Hasil Belajar Siswa,” *J. Ilm. Pendidik. Fis.*, vol. 6, no. 3, p. 560, 2022.

[27] M. Fetra Bonita Sari, Risda Amini, “Jurnal basicedu. Jurnal Basicedu,” vol. 5, no. 3, pp. 3(2), 524–532, 2020.

[28] S. H. Vina Yuniar, “Pengaruh Model Pembelajaran PBL Berbasis STEM Menggunakan Bantuan Mind Mapping Terhadap Peningkatan Kemampuan Berpikir Kreatif,” vol. 3, no. 1, pp. 31–41, 2023.

[29] M. Baptista and I. Martins, “Effect of a STEM approach on students’ cognitive structures about electrical circuits,” *Int. J. STEM Educ.*, vol. 10, no. 1, 2023.

[30] A. D. Wahyuningtyas, P. D. A. Putra, and U. Nuha, “The Effect of the Problem Based Learning using STEM Approach on Higher Order Thinking Skills and Learning Activities in Julior High School Students,” *J. IPA Pembelajaran IPA*, vol. 7, no. 2, pp. 166–176, 2023.

[31] D. Murdiasih and F. E. Wulandari, “Model Problem Based Learning dengan Pendekatan STEM terhadap Kemampuan Berpikir Kreatif Siswa,” *JIPVA (Jurnal Pendidik. IPA Veteran)*, vol. 3, pp. 962–967, 2022.