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# The Effectiveness of the POLA (Lantern Light Project) STEM-PJBL Model in Fifth-Grade Student Engagement and Higher-Order Thinking Skills

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**Abstract**
Science learning requires active engagement and critical thinking to understand science concepts. In order to achieve this goal, learning must be contextualized, using the right model and supporting teaching aids. This quantitative experimental research aims to evaluate the effectiveness of the STEM-PJBL-based POLA (Light Lantern Project) learning model on the properties of light in grade V, with a focus on student activeness and higher-order thinking skills (HOTS). Using a one-group pretest posttest design and paired sample T-test analysis, this study shows that the application of the STEM-PJBL-based POLA model increases student engagement and HOTS. The use of props effectively encourages active participation, curiosity, and student motivation. Students also developed 21st-century skills, such as critical thinking, creativity, collaboration, and problem-solving. The findings suggest that the STEM-PJBL-based POLA model is effective in improving the quality of science learning, particularly the properties of light, as well as student engagement and higher-order thinking skills. This model can be a strategic approach to increase student engagement and develop 21st-century skills, as well as support a more meaningful learning experience.

**Keywords:** STEM-PJBL; Student Engagement; HOTS

## INTRODUCTION

Rapid changes and technological complexity globally occur in the 21st century. Technological developments, globalization, and various new challenges demand changes, especially in the education sector, one of which is at the primary school level. Education at the primary school level has a very important role in forming the basis of students' understanding and skills. Therefore, changes in primary school education are essential to create a resilient, creative and innovative generation to welcome the dynamics of the 21st century (Thana & Hanipah, 2023). The education standards provided in Indonesia require the focus and implementation of twenty-first century skills from 4Cs to 5Cs as the main reference of autonomous learning curriculum, including communication, cooperation, creativity, critical thinking, and character in current learning. These abilities can be aggressively cultivated through classroom learning activities. The 5Cs, namely critical and creative thinking, are included in HOTS (Ayu & Murni, 2023).

HOTS involves critical, creative and analytical thinking, all of which are essential for effective problem solving (Suparman, 2021). Science education, in particular, requires students to think critically, creatively, and analytically in response to information and data to solve problems. Science learning is not just about memorizing concepts, but also involves discovery and exploration through the scientific process (Muliani, 2022). At the elementary school level, science should be linked to real life or contextual issues, as elementary school-aged children are still developing concrete operational thinking (Azzahra et al., 2023). HOTS-based learning increases the cognitive level, making problem solving easier by encouraging students to think critically and creatively (Yusuf et al., 2020).

Along with the efforts to integrate HOTS in learning, the application of POLA (Light Lantern Project) can be an effective alternative to improve students' critical, creative, and analytical thinking skills. POLA, which is based on the STEM-PJBL approach, focuses on the application of science concepts through project-based activities relevant to real life, such as the exploration of the properties of light. This study analyzes the effectiveness of POLA in increasing students' engagement in science learning, as well as evaluates its effect on the 5C skills, including communication, collaboration, creativity, critical thinking, and student character at the elementary school level. Thus, the application of POLA not only improves students' cognitive skills, but also creates a more meaningful and contextualized learning experience.

In addition, the POLA model emphasizes collaboration between students, as they will work in groups to design and complete projects together. This approach encourages effective communication and a more interactive learning atmosphere, which in turn can increase student engagement in the learning process. With the implementation of this model, students are expected to develop critical 21st century skills, including creativity, problem solving and cooperation in the context of science learning.

HOTS-oriented instruction varies from typical teaching approaches because it trains students to think critically and creatively, communicate effectively, solve issues, and actively engage in comprehensive skill development (Qiftiyah, 2023). Teachers must first understand the characteristics of HOTS-oriented instruction before implementing it in the classroom. To enhance HOTS, teaching, and learning activities should be student-centered, foster creativity, be engaging and meaningful, and incorporate "learning by doing" (Syam & Suharto, 2023). Students are encouraged to actively explore, discover knowledge, and create artifacts or evidence within a contextually relevant environment, which requires both physical and mental preparation (Fadillah et al., 2022).

Integrating HOTS into instruction fosters changes in students, making them more engaged learners- emotionally, cognitively, and behaviorally. This aligns with Sofyan & Fihtanti (2020) the assertion that HOTS-integrated learning encourages active student involvement by fostering complex understanding, which also promotes values such as communication, tolerance, cooperation, and respect for others' opinions. Thus, HOTS-integrated learning not only improves students' cognitive abilities, however it also improves their interest and active participation in the educational process.

Previous research shows various learning models that can improve HOTS and student engagement, such as STEM-PJBL which has been proven effective in improving HOTS and student engagement in science learning (Andriani et al., 2023) found that the PJBL learning model can increase HOTS and the involvement of students in learning science in grade IV, but needed to specifically explain the indicators of student involvement with increased student involvement.

In research (Rahman et al., 2023) the STEM approach has been shown to increase students' HOTS, although the relationship between model syntax and indication improvement has yet to be addressed.

Then in research Niza et al., (2024), PJBL learning model will be capable of improving students' HOTS and communication between teachers and students with other students in science learning tools IV. Based on these findings, the STEM approach can be integrated to increase students' involvement in learning and students' HOTS. Integrating STEM with PJBL can be an effective approach to support students' comprehension, as it provides hands-on practice rather than focusing solely on theoretical content (Maryani et al., 2021). This combination enables students to analyze issues, formulate responses, and generate solutions, thereby offering valuable learning experiences (Dywan & Airlanda, 2020).

The STEM-integrated PJBL model offers multiple advantages. First, it cultivates not only student skills but also moral and ethical awareness (Taylor & Taylor, 2020). Additionally, this model promotes critical and creative thinking while fostering collaboration and communication through group-based activities. Instructional aids play a crucial role in achieving educational objectives. Integrating these aids within the STEM-PJBL model is instrumental in providing a contextual comprehension to subject ideas (Martaningsih et al., 2022). Using educational tools to enhance the learning process engages students, stimulating their interest and motivation to learn. Effective instructional aids meet the criteria of validity, ease of use, and efficiency. Valid instructional aids align with content and conceptual requirements and are designed to be visually appealing. Ease of use ensures that students can handle these aids effortlessly during activities, while student learning outcomes measure effectiveness (Acar et al., 2018).

However, challenges persist in the learning process, contributing to students' low HOTS and limited engagement. Key issues include reliance on ineffective teaching methods, such as teacher-centered learning, where students passively listen to the teacher's explanations (Hairunisa, 2023). This approach often needs to improve comprehension, particularly in science, a subject that demands active student participation for exploration and discovery (Diana et al., 2022). Additionally, many educators continue to use Lower-Order Thinking Skills (LOTS) in instruction, limiting students' cognitive development (Maryani & Martaningsih, 2020). A lack of instructional aids or media in science education, which requires visual support to convey complex material effectively, further hinders student comprehension (Winangsih & Harahap, 2023).

Therefore, this study aims to evaluate the effectiveness of POLA (Light Lantern Project), a STEM-PJBL-based approach, in improving HOTS and engagement of fifth grade students in science lessons, focusing on the properties of light. The model is expected to provide a more engaging and holistic learning experience for students, and support the development of skills relevant to the demands of the 21st century.

## METHOD

This study used quantitative methods, namely the type of quasi-experimental design, with a one-group posttest-pretest design. Data were analyzed using descriptive statistics and prerequisite tests, such as normality and homogeneity tests (Teacher Education, 2020). Meanwhile, nonparametric tests, including the Wilcoxon signed test, were used to assess the hypotheses. Then, Cohen's d was used to determine the level of response to variables (Vogt, 2015). The study population consisted of 145 fifth-grade children of Muhammadiyah Condongcatur Elementary School in the Special Region of Yogyakarta, divided into classes 5-A, 5-B, 5-C, and 5-D. The sample was randomly drawn from one class, 5-B, which included 32 students, using simple random sampling to ensure that each student had an equal chance of being selected (Rashid, 2022).

SD Muhammadiyah Condongcatur was selected as the research site based on adequate facilities for science experiments and previous experience using traditional teacher-centered learning methods. This school was chosen because it has the potential to implement the project-based learning (STEM-PJBL) designed in this study, which would improve HOTS skills and student engagement. The research instrument consisted of a test with questions to assess the variables of interest. Data collection began with a pretest to assess students' basic skills. After the pretest, students were introduced to the learning materials, engaged in discussions, organized the materials, and given project assignments. Students work in groups to develop the project, present their results, summarize the learning content, and get feedback from peers. After completing the project, a posttest was administered to conclude the data collection. This study used nonparametric methods for hypothesis testing because the sample was limited, and the data obtained was on an ordinal scale. Thus, it is more suitable to analyze using nonparametric statistical tests. The Wilcoxon signed-rank test was used to evaluate differences before and after treatment, which allows analysis. Table 1 show the observation aspects of students' involvement.

**Table 1. Observation Aspects of Students' Involvement**

| Variable | Indicator | Aspect observed |
|---|---|---|
| **Learner Engagement** | **Discuss** | 1) Dare to express opinions |
| | | 2) Dare to answer questions |
| | | 3) Initiative |
| | | 4) Rigor |
| | **Presenting** | 5) Mastering presentation materials |
| | | 6) Presents the material systematically |
| | | 7) Demonstrate skills in the use of media |
| | | 8) Answering questions from group participants |
| | **Expressing an Opinion** | 9) Expressing opinions clearly |
| | | 10) Expressing opinions with polite language |
| | | 11) Expressing opinions appropriately by the material |

Table 2 shows how the questions are used to measure students' HOTS. The pretest questions have the same indicators as the posttest, but with different question formats.

**Table 2. Pretest and Posttest Instrument Outline**

| HOTS | Indicator | Item |
|---|---|---|
| Analysis (C4) | Given an illustration, learners can analyze the application of light in everyday life. | 1 |
| Analysis (C4) | Presented with a picture, learners can analyze the nature of light in daily life and natural and artificial light sources. | 2 |
| Evaluate (C5) | Presented with a picture illustration, learners can evaluate the types of light sources and properties of light in everyday life. | 3 |
| Evaluate (C5) | Presented with a picture, learners can prove the application of light and the properties of light in everyday life. | 4 |
| Creations C6) | Presented with a picture, learners can categorize the properties of light in everyday life. | 5 |
| Creations (C6) | Presented with illustrations, learners can conclude and organize the properties of light in everyday life. | 6 |

## RESULTS AND DISCUSSION

### Results

This study found that using instructional tools within the PJBL paradigm, paired with a STEM approach in fifth-grade science lessons on the characteristics of light, boosts both student engagement and HOTS. Using instructional aids within the PJBL-STEM framework promotes active student participation, instills interest, and boosts motivation throughout the learning process. As a result, students not only gain a better comprehension of the topic, but they also acquire important 21st-century abilities like critical thinking, creativity, cooperation, and problem-solving. This study was carried out in a single class, VB, across three learning sessions, using organised steps from the PJBL-STEM approach to teach the science topic of light qualities.

In the first session, students were introduced to fundamental questions and given a pretest to assess their prior knowledge. The next step involved designing a project plan with the aid of "Lantern Light Project" (POLA) worksheets, which guided group discussions on project planning. This was followed by students and the teacher collaboratively scheduling tasks for the POLA project. In the second session, project progress was monitored as students began constructing their projects with the teacher acting as a facilitator. Students conducted preliminary tests of their POLA projects in preparation for their final presentations. The third session then focused on project completion, during which students presented their completed POLA projects, received feedback, and evaluated their outcomes. After all learning activities were completed, students took a posttest to measure their newly acquired skills.

The PJBL model, integrated with STEM and instructional aids, enabled students to participate actively, experiment, and enhance their HOTS. The results of students' involvement and HOTS in learning science about the nature of light can be observed in Table 1. provides descriptive statistics learner engagement; Table 2 provides normality test for learner involvement; Table 3 provides test of homogeneity of variances of learner engagement; Table 4 paired sample t-test/Wilcoxon test of learner engagement; Table 5 Cohen's d learner engagement; Table 6 provides descriptive statistics student HOTS; Table 7 tests of normality student HOTS; Table 8 test of homogeneity of variances students' HOTS; Table 9 paired/Wilcoxon test students' HOTS; Table 10 cohen's students' HOTS.

**Table 3. Descriptive Statistics Learner Engagement**

| | N | Minimum | Maximum | Mean | Std. Deviation |
|---|---|---|---|---|---|
| Pretest | 32 | 36 | 64 | 48.59 | 9.189 |
| Posttest | 32 | 55 | 91 | 78.91 | 9.317 |
| Valid N (listwise) | 32 | | | | |

The data presented in Table 3 shows a significant change in the level of learner engagement between the pretest and posttest after the application of the STEM-PJBL-based POLA learning model. In the pretest, the average engagement of learners was 48.59 with a range of scores between 36 and 64. This range reflects a relatively low initial engagement, where many students have not shown active participation in learning. However, after the implementation of the STEM-PJBL-based POLA (Lantern Light Project) project, the average engagement increased sharply to 78.91, with a minimum score of 55 and a maximum of 91. This shows that the applied learning model successfully motivates and engages students more intensely in the learning process regarding the properties of light. This significant increase can be attributed to the characteristics of project-based learning that encourages active participation, exploration and application of knowledge in a real context.

The relatively consistent standard deviation between the pretest (9.189) and posttest (9.317) indicates that although the average engagement score increased, the variation in engagement levels between students remained stable. That is, even though there were students who started with a low level of engagement, they still experienced similar improvements to students who were already more actively engaged at the beginning. This indicates that the STEM-PJBL-based POLA learning model successfully benefited all students, both the more passive and the more active ones, in improving their engagement. Overall, these findings provide insight that project-based approaches such as POLA not only increase student engagement, but can also even out engagement levels across the class, encouraging more inclusive participation and stimulating student curiosity in learning scientific concepts.

**Table 4. Normality Test for Learner Involvement**

| | Kolmogorov-Smirnov[a] | | | Shapiro-Wilk | | |
|---|---|---|---|---|---|---|
| | Statistic | Df | Sig. | Statistic | Df | Sig. |
| Pretest | .257 | 32 | .000 | .857 | 32 | .001 |
| Posttest | .224 | 32 | .000 | .893 | 32 | .004 |

a. Lilliefors Significance Correction.

The normality test results (Kolmogorov-Smirnov and Shapiro-Wilk) in Table 4 show that the pretest and posttest data are not normally distributed, with p values $<0.05$ for both tests. This indicates a violation of the normality assumption in both groups. Therefore, subsequent analysis should use a non-parametric approach, such as the Wilcoxon test, to ensure valid and reliable results. The normality test using Shapiro-Wilk revealed that both data were regularly distributed. During the pretest engagement, the Kolmogorov-Smirnov test produced a statistic of 0.257 with a significance value (Sig.) of 0.000, whereas the Shapiro-Wilk test produced a statistic of 0.857 with a p-value of 0.001. Both suggest that the pretest data distribution violates the premise of normality. A similar pattern was observed in the posttest engagement, with the Kolmogorov-Smirnov test yielding a statistic of 0.224 with a p value of Sig. 0.000 and the Shapiro-Wilk test yielding a statistic of 0.893 with a p-value of 0.004. Thus, these findings show that neither the pretest nor the posttest data are normally distributed, implying that following statistical analysis should employ non-parametric approaches to guarantee that the analytical results are legitimate in the setting of the research.

**Table 5. Test of Homogeneity of Variances of learner engagement**

| | | Levene Statistic | df1 | df2 | Sig. |
|---|---|---|---|---|---|
| Engagement | Based on Mean. | .003 | 1 | 62 | .953 |
| | Based on Median. | .057 | 1 | 62 | .812 |
| | Based on Median and with adjusted df. | .057 | 1 | 57.297 | .812 |
| | Based on trimmed mean. | .000 | 1 | 62 | .995 |

Table 5. The result of the homogeneity of variances test for engagement indicates that the variation between the pretest and posttest groups is equal or homogenous. In the mean-based analysis, the Levene Statistic yields a value of 0.003 with a significance level (Sig.) of 0.953, indicating no significant difference. Similarly, the median-based analysis yielded a value of 0.057 and Sig. 0,812. The adjusted median test produced comparable findings. However the trimmed mean analysis yielded a value of 0.000 and Sig. 0,995. All of these findings suggest that the variances between the two groups are not significantly different. In other words, we may proceed with following statistical studies, such as the t-test or ANOVA, knowing that the assumption of equal variance has been fulfilled.

The results of the homogeneity of variance test in Table 5 show that there was no significant difference in variance between the pretest and posttest groups. The very high significance values ($p > 0.05$) in all analyses (mean, median, and trimmed mean) indicated that the variances of the two groups were homogeneous. This means that differences in variance did not affect the results of the analysis, and the assumption of equal variance was met. Therefore, further statistical analyses, such as t-test or ANOVA, can be conducted with confidence that the results are reliable.

**Table 6. Paired Sample T-test / Wilcoxon Test of Learner Engagement**

| | | N | Mean Rank | Sum of Ranks |
|---|---|---|---|---|
| Posttest_involvement - Pretest_Involvement | Negative Ranks. | 0[a] | .00 | .00 |
| | Positive Ranks. | 32[b] | 16.50 | 528.00 |
| | Ties. | 0[c] | | |
| | Total | 32 | | |

a. Posttest_engagement < Pretest_engagement
b. Posttest_engagement > Pretest_engagement
c. Posttest_engagement = Pretest_Engagement

Tabel 6. The results of the analysis using the *Wilcoxon Signed Ranks* test showed significant differences between posttest and pretest engagement. Out of a total of 32 learners, none showed negative ratings (posttest lower than pretest). In comparison, 32 learners showed positive ratings (posttest higher than pretest), with an average positive rating of 16.50 and a total rating of 528.00. *Wilcoxon* Signed Ranks test results showed a significant increase in engagement in all learners after implementation. No participants experienced a decrease in engagement, indicating that the STEM-PJBL approach in the Light Lantern Project was effective in consistently increasing engagement. These results also reflect the success of the project-based method in motivating students, including those who were initially less engaged, and reinforce the importance of applied and collaborative learning to encourage active participation across student groups.

**Tabel 7. Test Statistics[a]**

| | Posttest_involvement - Pretest_Involvement |
|---|---|
| Z | -4.953[b] |
| Asymp. Sig. (2-tailed) | .000 |

a. Wilcoxon Signed Ranks Test
b. Based on negative ranks.

The statistical test yielded a Z value of -4.953 with a significance (Asymp. Sig.) of 0.000. This very small p value (well below 0.05) indicates that the difference between pretest and posttest engagement is significant. In other words, these results indicate that the intervention was successful in increasing learners' engagement consistently across groups. In addition, the findings suggest that project-based approaches such as STEM-PJBL can have a consistent and positive impact on student engagement, whether initially less engaged or more engaged. This underscores the importance of using more interactive methods based on hands-on application of materials to increase student motivation and understanding in the context of science learning. As an additional insight, the use of STEM-based projects can also stimulate the development of collaboration and problem-solving skills that are important for students' 21st century readiness.

**Table 8. Cohen's d Learner Engagement**

| Engagement | Average | Standard Deviation | Cohen's d | Description |
|---|---|---|---|---|
| Pretest<br>Posttest | 30.3125 | 9.4679 | 3.201608 | Very Large |

Table 8 shows an average of 30.31, a standard deviation of 9.46, and a Cohen's d value of 3.20, which falls into the very large category. This indicates that the Pattern (Lantern Light Project) Based on STEM-PJBL in the Class V Light Properties Material is very effective in engaging students. The application of the STEM-PJBL method is not only effective in increasing student engagement, but can also encourage the development of critical and creative thinking skills, which are very important in 21st century education. This approach provides a more thorough and contextualized learning experience, encouraging students to be more active in exploration and problem solving.

**Table 9. Descriptive Statistics Student HOTS**

| | N | Minimum | Maximum | Mean | Std. Deviation |
|---|---|---|---|---|---|
| HOTS_Pretest | 32 | 33 | 100 | 68.78 | 15.616 |
| HOTS_Posttest | 32 | 67 | 100 | 78.16 | 12.094 |
| Valid N (listwise) | 32 | | | | |

Table 9. shows the higher order thinking skills (HOTS) on the pretest and posttest of the 32 learners. On the pretest, the HOTS scores had an average of 68.78, with a minimum score range of 33 and a maximum of 100. This indicates that, although there was considerable variation in learners' thinking ability before the intervention, the average was still in a relatively moderate

range. After the intervention, the posttest HOTS scores increased to an average of 78.16, with a minimum score range of 67 and a maximum of 100. This average increase reflects a significant development in learners' higher order thinking skills after the implementation of the STEM-PJBL project-based learning approach. In addition, the standard deviation for the pretest was 15.616, while for the posttest it decreased to 12.094, indicating that despite the improvement, the variation among learners became smaller after the intervention. These results suggest that the applied method was not only successful in improving HOTS, but also in reducing inequality in learners' abilities. The application of STEM-PJBL focuses not only on improving academic knowledge, but also on developing critical and creative thinking skills that are essential in facing 21st century challenges. The application of this approach can facilitate learners to be more active in identifying problems, designing innovative solutions, and thinking analytically, which are important aspects of HOTS.

**Table 10. Tests of Normality Student HOTS**

| | Kolmogorov-Smirnov[a] | | | Shapiro-Wilk | | |
|---|---|---|---|---|---|---|
| | Statistic | df | Sig. | Statistic | Df | Sig. |
| HOTS_Pretest | .205 | 32 | .002 | .908 | 32 | .010 |
| HOTS_Posttest | .291 | 32 | .000 | .771 | 32 | .000 |

a. Lilliefors Significance Correction.

Tabel 10. The normality test results for HOTS showed that the data for the pretest and posttest were not normally distributed. In the pretest HOTS, the Kolmogorov-Smirnov value was 0.205 with a significan (Sig.) of 0.002, while the Shapiro Wilk test produced a statistical value of 0.908 with a p-value of 0.010. Both results indicate that the pretest HOTS data distribution does not meet the normality assumption. Similarly, in the posttest HOTS, where the Kolmogorov-Smirnov value reached 0.291 with a Sig. 0.000, and the Shapiro wilk value was 0.771 with a p-value of 0.000. These results indicate that the posttest data is also not normally distributed. Thus, further statistical analysis should consider non-parametric methods because the normal assumption is not met in both groups of HOTS data. The non-normality of the distribution may have been influenced by the significantly varying characteristics of the data in both the pretest and posttest, indicating that learners had very different levels of HOTS ability. This reinforces the importance of using more flexible methods to analyze non-normally distributed data.

**Table 11. Test of Homogeneity of Variances Student HOTS**

| | | Levene Statistics | df1 | df2 | Sig. |
|---|---|---|---|---|---|
| HOTS | Based on Mean. | .507 | 1 | 62 | .479 |
| | Based on Median. | .253 | 1 | 62 | .617 |
| | Based on Median and with adjusted df. | .253 | 1 | 57.431 | .617 |
| | Based on trimmed mean. | .459 | 1 | 62 | .501 |

Tabel 11. The results of the homogeneity of variances test for higher-order thinking skills (HOTS) showed that the variance between the pretest and posttest groups was homogeneous. In the analysis based on the mean, the Levene Statistic recorded a value of 0.507 with a significance (Sig.) of 0.479, indicating that there was no significant difference in variance between the two groups. The analysis based on the median also gave consistent results, with a Levene Statistic of

0.253 and a Sig. Value of 0.617. 0,617. The test with the adjusted median showed the same value, while the analysis based on the trimmed mean recorded a value of 0.459 with a Sig value. 0,501. All these results indicate that the variance between the two HOTS groups is not significantly different; thus, the assumption of homogeneity of variance can be accepted. This is important to ensure that subsequent statistical analysis, such as t-test or ANOVA, is valid and reliable. The homogeneity of variance achieved also suggests that although there was an increase in HOTS skills between the pretest and posttest, the changes were likely to be consistent across learners, without the possibility of being caused by large differences in the variability of each group. This strengthens the reliability of the research results and the conclusions that can be drawn from further analysis.

**Table 12. Paired/Wilcoxon test Student HOTS**

| | | N | Mean Rank | Sum of Ranks |
|---|---|---|---|---|
| HOTS_Posttest - HOTS_Pretest | Negative Ranks | 5[a] | 10.40 | 52.00 |
| | Positive Ranks. | 21[b] | 14.24 | 299.00 |
| | Ties. | 6[c] | | |
| | Total. | 32 | | |

a. HOTS_Posttest < HOTS_Pretest.
b. HOTS_Posttest > HOTS_Pretest.
c. HOTS_Posttest = HOTS_Pretest.

Tabel 12. the results of the analysis using the Wilcoxon Signed Ranks test showed a significant difference between posttest and pretest higher-order thinking skills (HOTS). Of the total 32 learners, five learners showed a negative rank (posttest lower than pretest) with an average rank of 10.40 and a total rank of 52.00. Conversely, 21 learners showed a positive rating (posttest higher than pretest) with an average rating of 14.24 and a total rating of 299.00. In addition, six learners showed no difference between the two measurements. Overall, the findings not only confirm the effectiveness of the learning approach, but also suggest that it can improve students' higher-order thinking skills, although there are some individuals who may need additional support. This approach could be extended by investigating the factors that influence students who do not show improvement, so that teaching can be better tailored to maximize the impact of learning.

**Tabel 13. Test Statistics[a]**

| | HOTS_Posttest - HOTS_Pretest |
|---|---|
| Z. | -3.200[b] |
| Asymp. Sig. (2-tailed) | .001 |

a. Wilcoxon Signed Ranks Test

The statistical test resulted in a Z value of -3,200 with a significance (Asymp. Sig.) of 0.001. This very small p-value indicates that the difference between posttest and pretest HOTS is significant. Practically, these results confirm that the intervention was successful in consistently improving learners' HOTS, although there were individual variations in the results achieved. The significant improvement in the majority of learners also indicates that the STEM-PJBL project-based learning method is effective in stimulating the development of critical and creative thinking skills, which are at the core of HOTS. Going forward, these results can serve as a basis for developing learning strategies that are more focused on improving HOTS in various educational contexts.Thus, it can be concluded that the intervention was successful in improving learners' higher-order thinking skills consistently, with most learners showing progress after the intervention.

**Table 14. Cohen's d Student HOTS**

| HOTS | Average | Standard Deviation | Cohen's d | Description |
|---|---|---|---|---|
| Pretest Posttest | 9.375 | 15.59518 | 0.601147 | Medium |

Table 14 shows an average of 9.37, a standard deviation of 15.59, and a Cohen’s d value of 0.60, which falls into the moderate category. This indicates that the effectiveness level of the STEM-PJBL-Based Pattern (Lantern Light Project) in the Class V Light Properties Material is moderate towards students' HOTS. Cohen's d was used to measure the extent of changes in HOTS skills and student engagement after applying the STEM-PJBL-based POLA model, which was measured through pretest and posttest. The data in this analysis combines pretest and posttest, where Cohen's d is calculated based on comparing pretest and posttest scores on the same group (the same students) before and after treatment. Thus, Cohen's d will measure the effect of applying the POLA model on the change in scores obtained by students, thus providing an overview of the magnitude of the impact of learning on improving HOTS skills and student engagement.

## Discussion

Many elements impact the learning process, including the model and method that best meets the demands of the content and students (Salamun, 2023). Many learning models may be used in the learning process. A STEM-PJBL includes math, science, technology, and engineering. It can enable students to produce goods, collaborate on projects, and design learning activities (Lely et al., 2020). As a consequence, kids will learn complicated concepts throughout the process. Furthermore, when integrated with a STEM perspective, the PJBL learning paradigm significantly increases student participation in the process of learning. This is according to the findings of Nurfaijah et al. (2021) who found that the learning model significantly improves students’s active engagement during the process of learning. This is because each level of the PJBL model of learning with the STEM approach demands students to actively engage in their education.

The STEM-PJBL learning model follows several structured steps, including identifying a driving question, designing a project plan, setting a project schedule, monitoring project progress, presenting and assessing results, and evaluating project outcomes (Adiniyah & Utomo, 2023). Science education on the properties of light is particularly well-suited to this model, as science instruction often requires hands-on activities to achieve learning objectives (Muliani, 2022). In the initial phase of the STEM-PJBL model, students are presented with a fundamental question and given a pretest to assess their baseline understanding. This contextual pretest on the properties of light enables students to engage with the questions, fostering motivation to analyze and discuss the inquiry with their peers (Manalu et al., 2024).

In the STEM-PJBL learning model, students are required to collaborate. This collaboration begins in the second stage, where students work together to design the project plan for POLA

(Lantern Light Project) within their groups. POLA serves as both a project and a learning tool for exploring the properties of light, offering a contextualized understanding of these properties. In this stage, students are encouraged to collaborate, discuss, and contribute ideas to the POLA project plan. This process not only fosters teamwork, discussion, and idea exchange but also challenges students to be creative in designing the POLA project (Aziz & Nurachadijat, 2023).

In the third stage, students, together with their teacher, establish a project schedule for POLA, setting a timeline and deadlines to ensure the project progresses smoothly and stays on track. Students are encouraged to actively voice their opinions and analyze and evaluate the project schedule with their group members (Purba et al., 2023).

The fourth stage involves monitoring the project's progress, with the teacher acting as a mentor to support students throughout the POLA project development. Students engage in group discussions and perform activities related to creating the POLA project. Beyond simple assembly and material cutting, students carry out STEM-related tasks (Science, Technology, Engineering, and Mathematics), such as measuring and testing outcomes, fostering both creativity and engagement in learning (Prajoko et al., 2023). This aligns with findings by (Firmantara et al., 2023). This indicates that hands-on project creation sharpens students' critical thinking, enhances group collaboration, and hones their ability to express ideas.

In the fifth stage, students present their POLA project results to the class. At this stage, they articulate their thoughts on the subject and critically evaluate their project outcomes with their group members. As they demonstrate the properties of light in their presentations, students connect the project to real-world applications. This stage promotes student engagement and fosters HOTS in learning (Science, 2024).

In the sixth and final stage, the teacher evaluates the project outcomes and reflects on the learning process with the students. This evaluation encourages students to analyze the challenges they encountered, evaluate their work, and discuss the subject matter, fostering both HOTS and deeper engagement in the process of learning.

The development of HOTS skills through this model is also relevant to the 21st century education goals, which require students to be able to think critically, creatively, and collaboratively. The findings showing an increase in HOTS in students after this intervention provide concrete evidence that the STEM-PJBL approach can optimize students' higher order thinking skills, in line with the guidance by Lely et al. (2020) on improving critical thinking skills through project-based learning.

For future follow-up research, it would be useful to explore the long-term impact of this project-based learning, including its influence on students' abilities in other subjects or in the context of daily life. Further research could also identify factors that influence the acceptance of the STEM-PJBL model by students and teachers, as well as its impact on the development of other skills, such as communication and problem solving.

This research contributes both theoretically and practically. Theoretically, this research enriches the literature on applying STEM-PJBL-based POLA in improving HOTS skills and student engagement, especially in science learning in elementary schools. The findings strengthen the understanding that project-based learning can encourage students' creativity, collaboration, and analytical skills. This research provides guidelines for teachers to develop more active and contextualized learning methods and for schools to integrate STEM approaches in the curriculum to improve students' motivation and understanding. The findings can also serve as a reference for education policymakers to design learning strategies that are relevant to the demands of 21st-century skills.

## CONCLUSION

### Conclusion

This study concludes that applying the POLA project in the STEM-based PJBL model effectively increases student engagement and HOTS skills in science learning on the nature of light. The project encouraged students to be more active in discussing, expressing opinions, and presenting results, which increased their motivation and confidence. However, this study has limitations. It was only conducted in one class with three meetings and focused on the nature of light, so the results may need to be more generalizable to other materials or contexts. Further research with a larger sample and various materials is needed for further confirmation.

### Recommendations

Based on these findings, it is recommended that the PJBL model with a STEM approach be implemented in an engaging way, encouraging students to think critically as they solve problems. Beyond cognitive development, the STEM-based PBL learning model should also integrate psychomotor and affective skills to create a well-rounded learning experience.

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