Enhancing Students' Higher-Order Thinking Skills Through Inquiry-Based e-LKPD on Boyle's Law

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Abstract - *This study aimed to examine the effect of higher-order thinking skills (HOTS) through the implementation of an inquiry-based electronic student worksheet (e-LKPD) on Boyle's Law material. The participants were students from class XI IPA 1, who served as the experimental group, and class XI IPA 2, who served as the control group at SMA Negeri 1 Pekalongan. A quasi-experimental method with a pretest-posttest group design was employed. The study involved two variables: the independent variable (the inquiry-based e-LKPD on Boyle's Law) and the dependent variable (students' higher-order thinking skills). Data were analyzed using N-gain analysis, an Independent Samples t-test, and an effect size calculation. The N-gain results showed an improvement in HOTS in the experimental group with a score of 0.65 (moderate category), while the control group scored 0.49 (also in the moderate category). The Independent Samples t-test produced a sig. (2-tailed) value of 0.000, indicating a significant difference in HOTS between the experimental and control groups. Additionally, the effect size analysis yielded a Cohen's d value of 1.715, classified as a large effect. These results indicate that the use of an inquiry-based e-LKPD had a substantial impact on enhancing students' higher-order thinking skills. In conclusion, implementing inquiry-based e-LKPD in teaching Boyle's Law significantly improves students' ability to think at higher cognitive levels.*

Keywords: *Boyle's Law; e-LKPD; Higher Order Thinking Skills; Inquiry*

INTRODUCTION

The rapid advancement of information technology in the 21st century has brought significant changes across various sectors, including education. In this context, students are required to master a range of competencies relevant to the demands of the times, both locally and globally. One of the essential competencies that students must develop is 21st-century skills, which include critical thinking, creative thinking, communication, and collaboration—commonly referred to as the 4C skills (Ichsan, 2021).

Among these four skills, critical and creative thinking are integral components of Higher Order Thinking Skills (HOTS). According to the revised Bloom's taxonomy by Anderson and Krathwohl, HOTS encompasses the abilities to analyze, evaluate, and create. Research has shown that mastering HOTS is essential to improving the quality of learning and student outcomes. For example, students with high levels of HOTS tend to demonstrate stronger creative and metacognitive abilities when solving problems (Septiani et al., 2021). Similarly, Marini et al. (2021) and Rahmawati et al. (2021) found that HOTS-based learning supports the development of critical and creative thinking, although most students still fall into the moderate category. Syahri and Ahyana (2021) further confirmed that HOTS can be enhanced through contextual approaches and analysis-based questions.

Despite its importance, many Indonesian students still struggle to develop HOTS. Ginting et al. (2020) reported that most students could only answer questions at lower cognitive levels, such as remembering and understanding. Another study by Feronica et al. (2021) revealed that only 30% of high school students were able to

correctly solve HOTS-based questions. Zaki et al. (2020) also found that junior high school students in Indonesia demonstrated weak analytical thinking skills, with an average score of only 45 out of 100 on HOTS-type questions. Furthermore, data from the Ministry of Education, Culture, Research, and Technology (2021) indicated that approximately 72% of students struggled to complete tasks requiring in-depth analysis and evaluation.

One of the main factors contributing to the low level of HOTS is the dominance of teacher-centered learning approaches, where the teacher serves as the sole source of information and students play a passive role. This method typically emphasizes memorization and repetition, rather than fostering analysis, evaluation, and creation—core elements of HOTS. Bhardwaj (2023) and Hafid (2023) emphasized that such traditional teaching methods hinder students' critical and creative thinking development. While the teacher-centered approach may still be useful in certain situations, such as classroom management or delivering foundational knowledge, it often falls short in promoting higher-order thinking (Wahyuni & Fitrawati, 2024).

The gap in Indonesian students' HOTS is further highlighted by the 2022 Programme for International Student Assessment (PISA) results. Only 25% of Indonesian students reached Level 2 or above in reading literacy (OECD average: 74%), 31% in mathematics (OECD average: 69%), and 34% in science (OECD average: 76%). In the creative thinking domain, only 31% achieved basic proficiency (Level 3), significantly below the OECD average of 78%. Furthermore, only 5% of Indonesian students were classified as top performers (Levels 5–6), compared to 27% in OECD countries.

In addition to instructional methods, the limited use of technology and interactive learning resources is another major barrier to the development of HOTS. Preliminary research by Anugerah (2023) found that the learning materials used by teachers—such as textbooks and student worksheets (LKPD)—lacked interactive features and failed to stimulate scientific activity, as they mostly contained only static content and questions. On the other hand, Sa'adah et al. (2020) demonstrated that interactive multimedia significantly enhanced students' critical thinking skills. However, Maishara et al. (2023) identified challenges such as poor internet connectivity, inaccessible or overly complex materials, and restricted access to online resources, which hinder the effective integration of technology into HOTS-focused instruction.

To address these challenges, there is a pressing need for more interactive and technologically integrated teaching materials, one of which is the use of electronic student worksheets (e-LKPD). These digital worksheets must be systematically designed, well-structured, and integrated with appropriate learning models. Research by Faizah and Jamila (2022) showed that e-LKPD based on Problem-Based Learning (PBL) significantly improved students' thematic learning outcomes compared to conventional textbooks. Additionally, studies by Amalia et al. (2022) and Distrik et al. (2022) confirmed that e-LKPDs using the Liveworksheet platform were valid, practical, and effective in enhancing learning performance. The implementation of STEM-based e-LKPDs in high school physics—particularly in dynamic electricity topics—also resulted in measurable improvements in students' scientific literacy and numeracy skills (Syaifudin, 2022; Sari et al., 2022).

To be effective, e-LKPD must be combined with learning models that support conceptual exploration and discovery, such as the inquiry learning model. Research by Sari et al. (2023) indicated that inquiry-based learning significantly enhanced students' HOTS in the human motion system topic. Hmelo-Silver et al. (2007) and Hwang (2015) also reported that inquiry learning, when combined with interactive technology, can increase students' critical thinking skills by 27% compared to traditional methods. Pedaste et al. (2021) and Distrik et al. (2020) further emphasized that inquiry-based approaches improve problem-solving and decision-making abilities.

Based on these findings, it is essential to further explore how the integration of inquiry-based e-LKPD can enhance students' HOTS. Although previous studies have demonstrated the effectiveness of inquiry models and e-LKPD separately, research that specifically combines both approaches—particularly within the context of Boyle's Law in senior high school physics—is still scarce. Given that Boyle's Law requires strong conceptual understanding and analytical thinking, this topic is highly relevant for HOTS-focused instruction. Therefore, this study is conducted to address that research gap, under the title: Enhancing Students' Higher-Order Thinking Skills Through Inquiry-Based e-LKPD on Boyle's Law.

RESEARCH METHODS

This study used a quasi-experimental design known as pretest-postest control group design. Both samples, namely the experimental group and the control group, underwent pretest and posttest. The subjects of this study were students of class XI IPA SMAN 1 Pekalongan in the odd semester of the 2024/2025 academic year. The sampling technique used was saturated sampling technique or total sampling. This technique is a sampling technique when all members of the population are sampled.

The samples selected were the experimental group (XI IPA 1) of 32 students and 32 students in the control group (XI IPA 2). The experimental group received treatment using the inquiry learning model supported by e-LKP for Boyle's Law material, while the control group received learning with the Direct Instruction learning model supported by PPT media on Boyle's Law material.

The e-LKPD developed by Anugrah (2023) uses those that will be distributed during learning activities. The instrument used to measure higher order thinking skills is a description question consisting of 8 questions. The questions of the higher order thinking skills test instrument were validated and assessed for reliability.

Data from the higher order thinking skills test results were then subjected to preliminary analysis which included homogeneity test and normality test. The hypothesis in this study is whether or not there is an influence between students' pretest and postest results through higher order thinking skills. The effect of inquiry learning model with e-lkpd support for Boyle's Law material. The hypothesis was tested using the N-gain test, hypothesis test with the help of N-gain, independent sample T-test with the help of IBM SPSS 25.

RESULTS AND DISCUSSION

Results

This study aims to determine the effect of the application of inquiry-based e-LKPD on students' higher order thinking skills on Boyle's law material. This research uses the quasi-experimental method.

The design of this study was with an experimental group that received inquiry-based learning treatment with the support of

e-LKPD on Boyle's Law material in class XI IPA 1, totaling 32 students. The control group that underwent direct instruction learning, namely class XI IPA 2 which amounted to 32 students.

The results were measured through the pretest and posttest scores of the higher order thinking skills test instrument. The results showed that the average pretest HOTS score of students in the experimental class was 22.75. Meanwhile, students in the control class had an average pretest score of 22.56. After the learning process, the posttest scores of both classes showed an increase compared to the pretest scores. The average posttest score in the experimental class was 73.34 and the average posttest score in the control class was 60.55. This data shows that the increase in the final ability of students in the experimental class is greater than students in the control class. The average results of the pretest and posttest of both classes can be seen in Table 1.

Table 1. Average score of pretest and posttest Higher Order Thinking Skills

Parameter	Experiment class		Control class	
	Pretest	***Posttest***	***Pretest***	***Posttest***
(1)	**(2)**	**(3)**	**(4)**	**(5)**
Number of student	32	32	32	32
Lowest score	9,38	62,5	12,5	46,88
Highest score	50	84,38	34,38	78,13
Maximum score	100	100	100	100
Average score	22,75	73,34	22,56	60,55
Standard deviation	8,25	6,04	6,34	8,39

The next step is to do the N-gain normality test to check whether the data is normally distributed or not. The normality of the N-gain of both classes shows that the experimental and control classes have a significance value> 0.05 or greater than 0.05, so the N-gain data of both classes are normally distributed. The n-gain normality data can be seen in Table 2.

Table 2. N-gain Data Normality Test Results

	Experiment Class	**Control Class**
Sig.	0,200	0,200
Decision	Data is normally distributed	Data is normally distributed

The homogeneity test of class *N-gain* was carried out to determine whether the *N-gain* of the experimental class and control class had homogeneous variants or not. The results of the data homogeneity analysis are listed in Table 3.

Table 3. Homogeneity Test Results of N-gain Data

Levene Statistic	*df1*	*df2*	*Sig.*	*Interpretasi*
2,746	1	62	0,103	Homogen

Based on the results of the homogeneity test conducted on the *N-gain* data, the *variance* value is 2.746 with a *sig.* of 0.103. Because the *sig.* value is greater than 0.05, the data has the same variance or homogeneous.

The N-gain test results are used to determine the increase in students' *higher order thinking skills* based on the results of *pretests* and post-tests conducted before and after treatment. The N-gain test results can be seen in Table 4.

Table. 4 Average N-gain Data

Class	Score Acquisition	
	Average *N-gain*	**Category**
Experiment	0,65	Medium
Control	0,49	Medium

Based on Table 4, it is known that from the *N-gain* data of 32 students, the average *N-gain* value of the experimental class is 0.65. This value falls into the moderate category. And from the *N-gain*

data of 32 students, the average *N-gain* of the control class was 0.49 and fell into the moderate category. Although the increase in *higher order thinking skills of* experimental and control classes is both in the moderate category, the increase in the experimental class is higher than the control class because the average *N-gain* of the experimental class is higher than the average of the control class.

Higher order thinking skills in this study were evaluated using indicators such as targeted thinking skills, constructing of theories, forming hypothesis, reasoning, analyzing, evaluating, elaborating, and problem-solving. The N-gain results for each indicator are listed in Table 5 and Table 6.

Table 5. N-gain results for each Indicator of Experimental Class

HOTS Indicator	Experiment Class	
	N-gain	**Category**
Targeted thinking skills	0,79	High
Constructing of theories	0,67	Medium
Forming hypothesis	0,64	Medium
Reasoning	0,64	Medium
Analyzing	0,56	Medium
Evaluating	0,66	Medium
Elaborating	0,63	Medium
Problem solving	0,69	Medium

Table 6. N-gain results for each Indicator of Control Class

HOTS Indicator	Control Class	
	N-gain	**Category**
Targeted thinking skills	0,74	High
Constructing of theories	0,60	Medium
Forming hypothesis	0,53	Medium
Reasoning	0,44	Medium
Analyzing	0,54	Medium
Evaluating	0,46	Medium
Elaborating	0,39	Medium
Problem solving	0,39	Medium

Based on the *N-gain* test results for each student HOTS indicator above, experimental and control class students have high categories for the first indicator and moderate categories for the other seven indicators.

The next stage, namely hypothesis testing which includes independent sample t-test and effect size test. Independent sample t-test is conducted to determine whether or not there is a difference in the average increase in students' higher order thinking skills in experimental and control classes. The results of the independent sample t-test can be seen in Table 7.

Table 7. Independent Sampe T-Test Results

Class	T	*Sig (2-tailed)*	Interpretation
Experiment Control	0,86	0,00	There is a difference

Based on Table 7. in the *equal variances assumed* column the *Sig* value. *(2-tailed)* of 0.00, the value is less than 0.05. The test results show that Ho is rejected and H_1 is accepted, which means that there is a difference in students' HOTS improvement between the experimental and control classes.

The effect size testing stage is carried out to determine how much influence the learning model used in the study has. The effect size test results can be seen in Table 8.

Table 8. Effect Size Test Results.

Class	*Cohen's d*	Interpretation
Experiment Control	1,715	Great

Based on Table 8, it can be seen that the *effect size* is 1.715 with a large category. The results of the test can be interpreted that the use of inquiry-based *e-LKPD* in this

study has a great influence on students' higher order thinking skills.

Discussion

The research was conducted to describe the effect of students' higher order thinking skills through the application of inquiry-based e-LKPD on Boyle's Law material. The research was conducted by giving *pretest* and posttest questions that train students' higher order thinking skills. The pretest was given to determine the level of students' initial abilities before being treated. While the posttest is used to measure the development of students' final abilities after being given treatment. The research was conducted using two classes, namely the experimental class and the control class. Learning in the experimental class was carried out using inquiry-based e-LKPD media while the control class learning used direct instruction learning.

Hypothesis testing in this study was carried out using the N-gain test, Independent Sample T-test, and effect size test. The N-gain test is known through pretest and posttest data from the control class and experimental class. Based on the data, the average N-gain test can be seen in Figure 1.

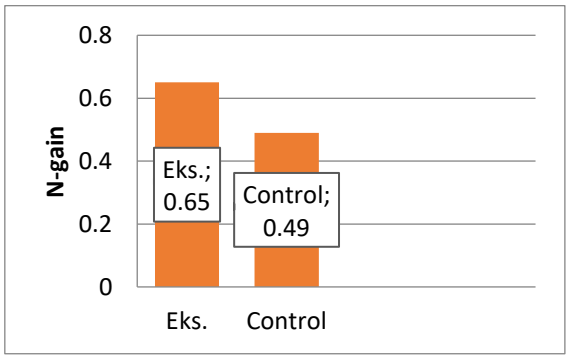


Figure 1. Graph of Average HOTS N-gain Results

Figure 1 shows the difference in the average N-gain scores of the experimental and control classes. From the figure it can be seen that the average result of the N-gain test in the experimental class is 0.65 with a moderate category. While the average N-gain score in the control class was 0.49 with a moderate category.

The independent sample T-test test was conducted on the N-gain data of the experimental and control classes to determine the difference in increasing students' higher order thinking skills between the experimental and control classes. The results of the independent sample t-test test in this study obtained a sig value. 2-tailed value of 0.000. The value is smaller than 0.005 which means H is rejected. The results of this test are evidence that there is a difference in the development of higher order thinking skills between the experimental class and the control class.

The effect size test was conducted to determine how much influence the learning model used in the study had. Based on the effect size test that has been carried out, the effect size is 1.548 with a large category. The results of the test can be interpreted that the use of inquiry-based e-LKPD in this study has a great influence on students' higher order thinking skills.

The results of hypothesis testing show that applying inquiry-based e-LKPD on Boyle's law material is effective for improving students' *higher order thinking skills*. This is in accordance with research conducted by Sembiring (2023) which states that the Inquiry Training learning model has a positive influence on students' HOTS abilities on impulse, momentum, and collision material. Then the research conducted by Panggabean (2022) This research shows that the application of the guided inquiry learning model is effective in improving students' HOTS abilities on dynamic electricity material in class IX SMP Budi Murni 4 Medan. Likewise, research also revealed the role of the creative inquiry

learning model in increasing HOTS (Distrik et al., 2019).

Students' higher order thinking skills are measured using a high-level thinking skills test instrument or HOTS with 8 items in the form of descriptions given before and after learning The following are the results of the N-gain test for each indicator of higher order thinking skills in each class.

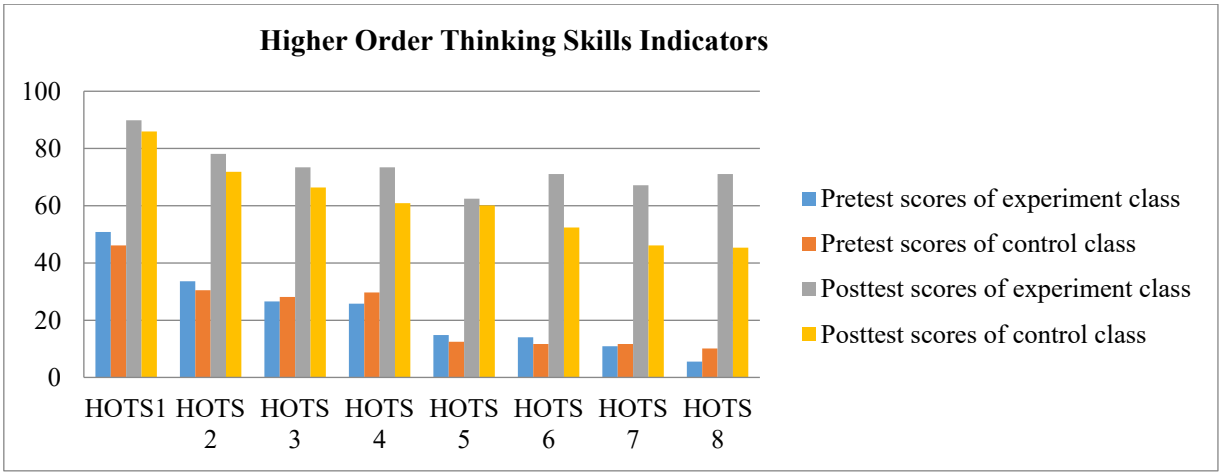


Figure 2. Percentage Chart of Students' *Higher order thinking skills*

The average *N-gain* obtained on the experimental class *targeted thinking skills* indicator was 79,37 (high category) and the average N-gain in the control class was 0.74 (in the high category). Based on these data, it is known that the increase in *targeted thinking skills* indicators in the experimental class is greater than the control class. The increase in *targeted thinking skills* indicators in the experimental class occurred because during the learning process students could understand the problem well. Fauzia, Badarudin, & Supriatna (2019) found that the guided inquiry learning model can train students to think purposefully and scientifically, thus developing problem-solving skills.

Activities that support the improvement of students' targeted thinking skills indicators are at the engagement stage. Providing phenomena at the engagement stage directs students to find out, analyze questions and seek deeper information about Boyle's law. At this stage of learning, students are directed to access video 1 contained in the e-LKPD as shown in Figure 3.

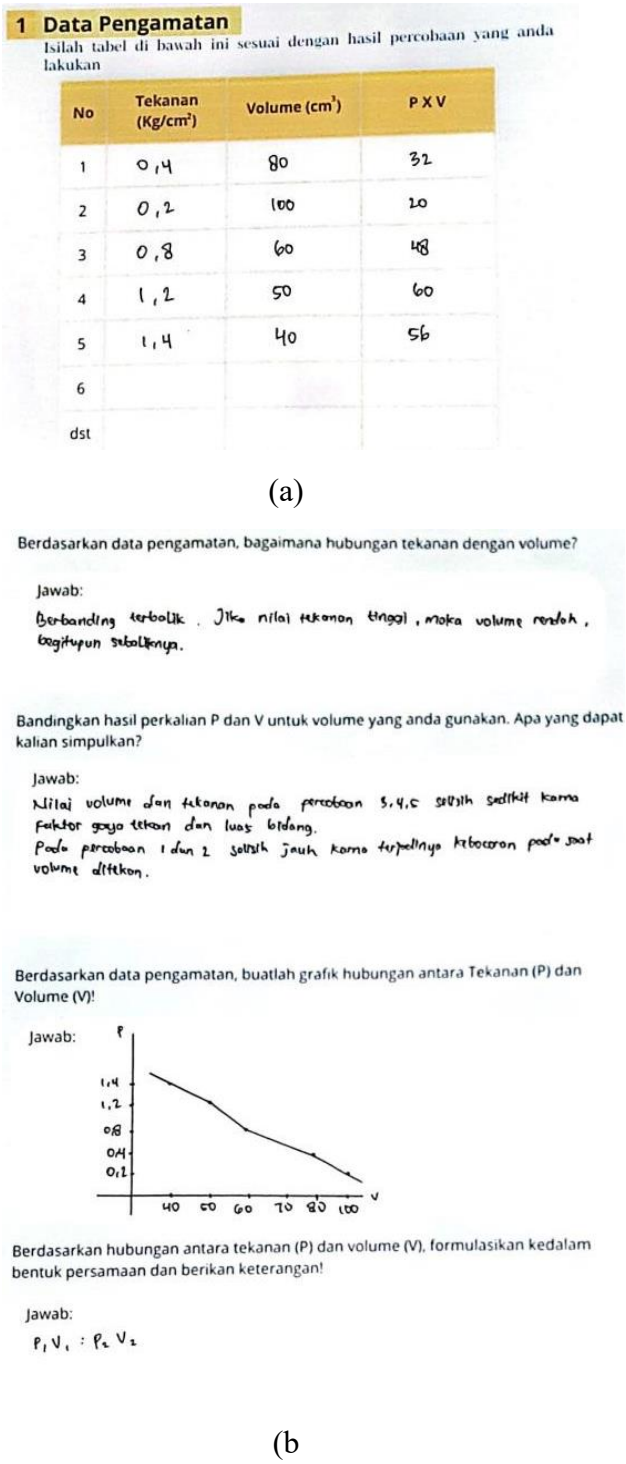
Figure 3. Activities that Support Indicators of Targeted Thinking skills of students

Providing phenomena in everyday life related to Boyle's Law through the video, students will be motivated, interested and trigger students' curiosity about the material to be learned which helps improve students' targeted thinking skills. Based on research conducted by Utami (2020), data obtained in cycle II, meeting I showed that students' higher-level thinking skills reached 71.4%. Meanwhile, at meeting II the observation results showed that the achievement had exceeded the target of 80.9%. This happened because the teacher had made improvements after reflection on cycle I.

The increase in targeted thinking skills indicators obtained the highest increase among other indicators. This is in line with research conducted by Arwin et. al (2025) which said that students' higher order thinking skills obtained that the indicator "Providing Simple Explanations" reached the highest percentage of 83.33% compared to other indicators. This shows that students more easily understand and master basic skills in providing simple explanations before developing more complex critical thinking skills or higher order thinking skills.

The *analyzing* indicator in the experimental class obtained an *N-gain* of 0.56 (medium) and in the control class of 0.46 (medium). Based on these data, it can be seen that the increase in *analyzing* indicators in the experimental class is greater than the control class.

The increase in analyzing indicators is trained through the explanation stage, where students record the results of the experiment. Then answer the questions contained in the e-LKPD by analyzing the data from the experiments that have been carried out in discussion with their respective groups. Through this stage students are trained to be able to analyze the experimental data and interpret it into a graphical form. The results of student analysis at this stage can be seen in Figure 4.



1 Data Pengamatan

Isilah tabel di bawah ini sesuai dengan hasil percobaan yang anda lakukan

No	Tekanan (Kg/cm²)	Volume (cm³)	P X V
1	0,4	80	32
2	0,2	100	20
3	0,8	60	48
4	1,2	50	60
5	1,4	40	56
6			
dst			

(a)

Berdasarkan data pengamatan, bagaimana hubungan tekanan dengan volume?

Jawab:

Berbanding terbalik. Jika nilai tekanan tinggi, maka volume rendah, begitupun sebaliknya.

Bandingkan hasil perkalian P dan V untuk volume yang anda gunakan. Apa yang dapat kalian simpulkan?

Jawab:

Nilai volume dan tekanan pada percobaan 3,4,5 selisih sedikit karna faktor gaya tekan dan luas bidang.
Pada percobaan 1 dan 2 selisih jauh karna terjadinya kebocoran pada saat volume ditekan.

Berdasarkan data pengamatan, buatlah grafik hubungan antara Tekanan (P) dan Volume (V)!

Jawab:

Berdasarkan hubungan antara tekanan (P) dan volume (V), formulasikan kedalam bentuk persamaan dan berikan keterangan!

Jawab:

$P_1 V_1 = P_2 V_2$

(b

Figure 4. (a) students' experiment data (b) students' analyzed answers

N-gain analysis obtained the smallest score because there were still many students who had difficulty in interpreting the experimental data into the concept of Boyle's law. Some students still have difficulty

making precise graphs so that the results match the concept. Hikmah, Putri, Nisa and Jauhariyah's research (2021) shows that the average percentage of students' ability to analyze (C4) is 67.49%, while the ability to evaluate (C5) reaches 80.46%. This indicates that the improvement in the analyzing indicator is lower than the evaluating indicator. Then research by Gunawan et al (2022) The results showed that students' analyzing ability was in the low category with a percentage of 29.83%, while the ability to evaluate and create was in the very low category with a percentage of 7.61% and 12%, respectively. Although the percentage of analyzing ability is higher than other indicators, overall the increase is still relatively low.

Based on the results of the hypothesis test that has been carried out by researchers, it shows that the increase in students' higher order thinking skills in the experimental class is higher than the control class. This means that the use of inquiry-based e-LKPD on Boyle's law material has a great influence on students' higher order thinking skills. This is in line with research conducted by Sari et at (2023) showing that there is a significant effect of inquiry learning models on improving students' higher order thinking skills. Then Drastisianti et al (2024) stated that the application of guided inquiry learning models supported by PhET simulations can improve students' higher order thinking skills in chemistry. The results of the analysis showed a significant increase in students' analysis, evaluation, and creation skills.

CONCLUSION

Based on the results of the study and the subsequent analysis, it can be concluded that the use of an inquiry-based e-student worksheet (e-LKPD) has a significant effect on students' higher-order thinking skills in the topic of Boyle's Law. This conclusion is supported by the results of the Independent Samples t-test, which showed a significance value (Sig. 2-tailed) of less than 0.05, and by the effect size calculation, which yielded a value of 1.715. This indicates that the inquiry-based e-LKPD had a strong impact on improving students' higher-order thinking skills.

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