ISSN (PRINT) : 2549-9955 ISSN (ONLINE): 2549-9963
JURNAL ILMIAH PENDIDIKAN FISIKA
https://ppjp.ulm.ac.id/journals/index.php/jipf/index

Implementation of Conceptual Change Model - Computational Thinking (CCM-CT) to Increase Students' Conceptual Understanding in Pascal's Law

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Abstract

This research aimed to implement the Conceptual Change Model - Computational Thinking (CCM-CT) in enhancing students' conceptual understanding of Pascal's Law. This research used a quasi-experimental design with a pretest-posttest control-group design. The population for this research comprised all second-semester grade XI MIPA students in a public high school in Bandung City. The sampling method used was purposive sampling, specifically selecting students who had not previously studied Pascal's Law material. The sample included two classes: the experimental class, which received treatment through CCM-CT learning, and the control class, which underwent treatment using CCM learning. The experimental class consisted of 8 male students and 28 female students, while the control class consisted of 9 male students and 27 female students aged 15-17 years. The data collection technique for students' conceptual understanding used a Four-tier test instrument on Pascal's Law. The data analysis technique used the N-Gain test to assess the enhancement of students' conceptual understanding through activities to alter their conceptions during the learning process. The results revealed a distinction in conceptual understanding between students who utilized CCM-CT learning and those who employed CCM learning. The N-Gain pre-test and post-test values in the experimental class, which implemented CCM-CT learning, were 0.71, interpreted as "high," while in the control class applying CCM learning, the values were 0.62, interpreted as "enough." As a result, implementing CCM-CT proved to be an alternative teachers could utilize to enhance students' conceptual understanding. This was supported by the research findings, which demonstrated a higher level of concept understanding among students who underwent CCM-CT learning compared to those who underwent CCM learning.

Keywords: conceptual change model; computational thinking; conceptual understanding

Received : 27 December 2023
Accepted : 15 January 2024
Published : 27 February 2024
DOI : https://doi.org/10.20527/jipf.v8i1.11479

How to cite: Anfusiyah, D., Samsudin, A., & Danawan, A. (2024). Implementation of conceptual change model-computational thinking (CCM-CT) to increase students' conceptual understanding in pascal's law. *Jurnal Ilmiah Pendidikan Fisika*, *8*(1), 44-57.

INTRODUCTION

Physics is the basis of fundamental science that is developed in discussions about technology and knowledge (Gudmundsson, 2020; Kurniawan et al., 2019; Ramankulov et al., 2020). In physics learning, understanding concepts takes priority over learning achievement. Understanding physics concepts is critical in physics learning because mastering the concepts allows students' knowledge to last a long period, even if the learning material has been taught for a long time (Falloon, 2019; Ikbal et al., 2021; Rogers, 2021). Students with a good, broad, and deep comprehension of concepts can apply them in the learning process, problem-solving, and other situations. Aside from that, students' conceptual understanding must go beyond simply knowing them and must be able to connect one concept to another (Chen et al., 2016; Rogers, 2021; Yudatika & Jauhariyah, 2021). When students integrate their prior knowledge with new information, they will be more engaged in learning.

Based on the results of literature reviews from previous research, which assessed students' conceptual understanding in physics learning based on indicators in line with (Krathwohl & Anderson, 2010), the findings indicated that students' understanding of concepts fell within the medium category for question indicators related to explaining and concluding. However, other question indicators were categorized as belonging to a high level of understanding. Overall, the average student conceptual understanding score was >33.33%, categorized as moderate (Suherly et al., 2023). This shows that students' conceptual understanding has not met the minimum completeness criteria, which is one of the obstacles for students in learning physics.

Another obstacle in learning physics is the existence of errors in understanding concepts experienced by students, where studying physics requires a good understanding of concepts. According to (Meșe & Sevilen, 2021), two factors can influence the learning process and help students understand concepts: internal and external factors. Internal factors include student character, attitudes toward learning, learning motivation, self-confidence, and habits. Meanwhile, external factors that influence concept understanding are the environment, teachers, friends, and the learning model used by the teacher.

Apart from conducting a literature study, the researcher also conducted a preliminary study by interviewing one of the physics teachers at a public high school in Bandung City. Working on problems the teacher presents in static fluid material is perceived as straightforward, primarily due to the limited number of formulas involved. However, when assessing conceptual understanding in a static fluid, particularly Pascal's Law, it is noted to be relatively low at 50%. Interpreting this percentage in terms of conceptual understanding categorizes it as being in the medium category.

Apart from interviewing with one of the physics teachers at the school, this test instrument is used as a first step to find out the level of students' conceptual understanding of Pascal's Law. The level of students' conceptual understanding obtained during the preliminary study is shown in Table 1.

Table 1 Percentage of students' conceptual understanding of Pascal's Law material

Concept	No.	Percentage of Correct Answers (%)	Average (%)
Pascal's Law	1	32.4	28.9
	2	10.7	
	3	40.6	
	4	32.1	

Table 1 shows the level of students' conceptual understanding of Pascal's Law given during the preliminary study. The test instrument employed in the preliminary study comprised four questions, and the average percentage of students who could accurately answer the questions based on the concept was

28.9%, indicating a low category of understanding.

The approach that may be implemented to increase students' conceptual understanding is to change students' concepts to lessen the misconceptions that students suffer. One approach is to employ a model of students' conceptual principles as a suitable strategy for teachers to overcome challenges in the area, specifically by applying the Conceptual Change Model to physics learning in schools. This learning model aims to change existing conceptions such as beliefs, ideas, or ways of thinking in students (Y. T. Chen & Wang, 2016; Makhrus & Busyairi, 2022; Putri et al., 2022; Sari & Nasrudin, 2015). In addition, according to (Samsudin, 2023), the Conceptual Change Model (CCM) is a learning model that is often regarded as successful in reducing students' misconceptions. The Conceptual Change Model is a learning model that aims to change existing beliefs, ideas, or ways of thinking that require students by requiring students to become displeased with present conceptions and seek out new concepts that are understandable and make sense before conceptual restructuring occurs. According to Armagan et al. (2010), the advantages of implementing the Conceptual Change Model (CCM) learning are that students can discover new concepts through process skills and scientific attitudes. Moreover, students can ask questions and express their opinions freely.

In this research, the novel aspect is the application of Conceptual Change Model (CCM) learning utilizing an approach that guides students to think computationally or engage in Computational Thinking (CT). Computational Thinking (CT) involves a cognitive process in framing problems and devising solutions in diverse forms, executed efficiently (Kong et al., 2022). Thus, applying Computational Thinking (CT) in science learning can help students better understand scientific concepts and processes. As a result, this research aims to implement the Conceptual Change Model - Computational Thinking (CCM-CT) to enhance students' conceptual understanding of Pascal's Law.

METHOD

This research used a quantitative approach, employing a quasi-experimental design with a pretest-posttest control-group design (Creswell, 2014; Gopalan et al., 2020; Scher et al., 2015). Several researchers commonly used this design in educational research (Malik et al., 2018; Ozkan & Selcuk, 2016; Samsudin et al., 2019). This research included two classes: the experimental class received the CCM-CT learning treatment, and the control class received the CCM learning treatment. In each class, students underwent a pre-test before receiving the treatment, and a post-test was administered after the treatment, as illustrated in Table 2.

Table 2 Pretest-posttest control-group design

Class	Pre-test	Treatment	Post-test
Experiment	O_1	X_1	O_2
Control	O_1	X_2	O_2

Note:

O_1 : An initial test (pre-test) is carried out before treatment is given.

X_1 : Treatment given to students uses the CCM-CT in learning.

X_2 : Treatment given to students uses the CCM in learning.

O_2 : The final test (posttest) is carried out after being given treatment.

The research was carried out at one of the high schools in Bandung City, West Java. Geographically, the location of the research location was shown in Figure 1.

Figure 1 Research location map
Source: www.otomotif1.com

The population was all students in phase F or grade XI MIPA in a public high school in Bandung City. Meanwhile, the samples consisted of two classes selected from the total population: the experimental class, which received treatment with CCM-CT learning, and the control class, which received treatment with CCM learning. The experimental class consisted of 8 male students and 28 female students, while the control class consisted of 9 male students and 27 female students aged 15-17 years. The sampling technique employed for selecting samples was purposive sampling. This method involved the deliberate selection of samples based on specific considerations aligned with criteria and research objectives, facilitating the determination of the appropriate number of samples for the study (Reski et al., 2023; Samsudin et al., 2022; Suhandi et al., 2020).

The instrument used in this research was a Four-tier test designed for the subject matter of Pascal's Law. The test was structured in a four-tier format, aligning with the indicators of conceptual understanding as outlined by (Krathwohl & Anderson, 2010). These indicators encompassed interpreting, providing examples, classifying, summarizing, drawing inferences, comparing, and explaining. The Four-tier format for Pascal's Law consisted of four levels. Tier-1 involved multiple-choice questions with five options. Tier-2 included the level of confidence in the answers provided for tier-1 questions. Tier-3 comprised reasons presented in multiple-choice questions, corresponding to the answer choices from tier-1. Finally, tier-4 contained the level of confidence in the reasons given for the answers in tier-2. The preparation of the FTFST instrument used a 4D model containing four preparation stages: define, design, develop, and disseminate (Aripiani et al., 2023; Fratiwi et al., 2017; Suhardiman et al., 2022).

The data collection technique employed in this research was a measurement technique using tests. These tests were administered to students before treatment (pre-test) and after treatment (post-test). The data collected and processed through these measurements were quantitative.

After gathering research data from students' pre-test and post-test scores, the following step was to process and evaluate it. The first step in the data processing stage was to organize students' answers based on the concept understanding category, divided into four groups, as shown in Table 3. These included Sound Understanding (SU), Misconception (MC), Not Understanding (NU), and Errors (ER) (Ismail et al., 2015).

Table 3. Combination of Student Answers

No.	**Symbol**	**Category**	**Answer Combination**			
			Answer	**Confidence Rating Answer**	**Reason**	**Confidence Rating Answer**
1		(SU)	Correct	Sure	Correct	Sure

No.	Symbol	Category	Answer Combination			
			Answer	Confidence Rating Answer	Reason	Confidence Rating Answer
2		(MC)	Correct	Sure	Wrong	Sure
3			Correct	Not Sure	Wrong	Sure
4			Wrong	Sure	Wrong	Sure
5			Wrong	Not Sure	Wrong	Sure
6		(NU)	Correct	Sure	Correct	Not Sure
7			Correct	Sure	Wrong	Not Sure
8			Correct	Not Sure	Correct	Sure
9			Correct	Not Sure	Correct	Not Sure
10			Correct	Not Sure	Wrong	Not Sure
11			Wrong	Sure	Correct	Not Sure
12			Wrong	Sure	Wrong	Not Sure
13			Wrong	Not Sure	Correct	Not Sure
14			Wrong	Not Sure	Wrong	Not Sure
15		(ER)	Wrong	Sure	Correct	Sure
16			Wrong	Not Sure	Correct	Sure

Following the categorization of data based on the combination of students' answers, the next step involved calculating the percentage of students' answers. This calculation aimed to describe the level of students' understanding, as described in Equation 1.

$$P = \frac{f}{n} \times 100\% \qquad (1)$$

Note:

P : Percentage of individual concept understanding (%)

f : Many questions answered with a diagnosis of understanding the concept

n : A lot of test questions

After calculating the percentage of individual students' level of understanding, use Equation 2 to calculate the percentage of students' level of understanding for each concept.

$$R = \frac{\sum PK}{\sum S} \times 100\% \qquad (2)$$

Note:

R : Percentage of concept understanding level for each sub-concept (%)

$\sum PK$: The number of students who fall into the category of understanding the concept of each sub-concept

$\sum S$: Number of students taking the test

Students' conceptual understanding level was determined using the criteria stated in Table 4.

Table 4 Interpretation of concept understanding level

Percentage (%)	Criteria for level of understanding
$70 < PK \leq 100$	High
$30 < PK \leq 70$	Enough
$0 < PK \leq 30$	Low

To determine the increase in students' conceptual understanding after implementing Conceptual Change Model learning with a Computational Thinking Approach (CCM-CT), the results of students' pre-test and post-test were analyzed using the normalized gain (N-Gain) formula according to (Hake, 1998).

The results of calculating the N-Gain value obtained were then interpreted using the following criteria:

Table 5 N-Gain test criteria

N-Gain	Criteria
$\langle g \rangle > 0.7$	High
$0.3 \geq \langle g \rangle \geq 0.7$	Enough
$\langle g \rangle < 0.3$	Low

Changes in students' conceptions were determined by categorizing them.

(Hermita et al., 2017) revealed that the level of change in students' conceptions was determined into six categories: construction, disorientation, complementation, and students who already had the correct understanding. Then, (Samsudin et al., 2016) interpreted the category of changes in conception as generally divided into three, namely:

1) Acceptable Change (+) if changes are from a low conception level to a high conception level.
2) Not Acceptable (-) if changes occur from a high conception level to a low conception level.
3) No Charge is marked with the number zero (0) if there is no change in conception.

RESULTS AND DISCUSSION

Conceptual Change Model learning is a learning model that is oriented toward constructivism (Adriana Sari et al., 2021; Leuchter et al., 2020; Vosniadou et al., 2020). In this research, the conceptual change learning model was integrated with an approach that directed students to think computationally or computational thinking (CT).

Conceptual Change Model learning with a Computational Thinking Approach (CCM-CT) consists of several learning stages. The first stage involves the researcher identifying the level of understanding of the initial concept and students' confidence level in the concept of Pascal's Law. The second stage involved discussing the findings of the pre-test and post-test results. The third stage of the research aimed to challenge students' beliefs by applying computational thinking syntax. This process involved presenting a phenomenon and guiding students to formulate a problem, subsequently breaking down the problem into smaller, simpler parts to solve. Following this, still in the third stage and utilizing computational thinking syntax, students were guided to conduct actual laboratory practicums, analyze the results, and draw conclusions. Upon completing this stage, the research progressed to the fourth stage, which involved accommodating students' scientific concepts. Using computational thinking syntax, researchers directed students to scrutinize the disparities between their conceptions and the practical results they had obtained, aiming to enhance students' understanding of concepts. The fifth stage focused on reinforcing the conception acquired after confronting and accommodating the concept.

This learning approach was applied in one of the State High Schools in Bandung City to observe an improvement in students' understanding of concepts. The implementation involved using the Conceptual Change Model with a Computational Thinking (CCM-CT) approach in the experimental class and the Conceptual Change Model in the learning process for the control class. The levels of conceptual understanding for students in both the experimental and control classes were presented in Table 6.

Table 6 Average level of understanding of students' concepts in pascal's legal concepts

Class	Average of Conceptual Understanding		N-Gain	Interpretation
	Pre-test	Posttest		
Experiment	0.01	0.71	0.71	High
Control	0.01	0.62	0.62	Enough

The improvement in student's conceptual understanding before and after the implementation of learning in the two research classes was observed based on the N-Gain values provided in Table 5. These values were calculated using Equation (3) and interpreted according to the criteria outlined by (Hake, 1998) in Table 4.

Based on Table 5, the analysis results showed that the N-Gain value obtained from the pre-test and post-test results of CCM-CT learning in the experimental class was 0.71 with the interpretation of “high”, while the N-Gain value obtained from the pre-test results and the posttest of CCM learning students in the control class was 0.62 with the interpretation of “enough”.

These results indicated that both learning models, the CCM and the CCM-CT, improved students’ understanding of concepts. However, different outcomes were observed when considering the N-Gain values obtained in both classes. The N-Gain value obtained in classes that implemented CCM-CT learning was higher than in classes that implemented CCM learning. This meant that a learning model that was integrated with a method, approach, or learning support strategy could improve a better understanding of concepts in a lesson. The results of this research were in line with similar research conducted by (Zuhdi & Makhrus, 2020), which found that learning to change conceptions through unexpected questions could increase students’ understanding of concepts, as well as research conducted by (Juniartini et al., 2017), which found that Learning Conceptual Change Assisted by Phet Simulation could improve students’ conceptual understanding.

The enhancement in students' conceptual understanding, as indicated by the N-Gain pre-test and post-test scores, signified that students changed their conceptions after engaging in Conceptual Change Model learning. Throughout the learning activities, which included practicum exercises designed to modify students' conceptions, students were guided to reconstruct new concepts, ultimately acquired through these learning experiences. Changes in conception were analyzed by comparing the initial conceptions that students held before receiving treatment with the final conceptions obtained after the treatment. Students' conception categories were grouped according to the categories outlined by (Ismail et al., 2015). The initial conception of students in the experimental class obtained from the pre-test results was shown in Table 7.

Table 7 provides information regarding the average percentage for each conception category based on the pre-test and control results of students in the experimental and control classes. The SU category had an average of 3% for the experimental and 3% for the control classes. The MC category was 23% for the experimental and 18.5% for the control classes. The NU category comprised 73.5% of the experimental and 77.8% of the control classes. The ER category was also 3% for the experimental class and 3% for the control class. The NU category had the highest average percentage of the two research classes, at 73.5% and 77.8%, respectively. This indicated that many students, both in the experimental and control classes, still did not understand the concept of static fluids.

Table 7 Initial conceptions of experimental class and control class students

Question Item Number	**Conception Category Percentage (%)**							
	SU		**MC**		**NU**		**ER**	
	Ex	Con	Ex	Con	Ex	Con	Ex	Con
B1	0	0	25	14	75	83	0	3
B2	0	0	11	19	83	75	6	6
B3	0	0	39	22	61	78	0	0
B4	3	3	17	19	75	75	6	3
Average	3	3	23	18.5	73.5	77.8	3	3

Ex= Experiment; Con= Control; SU= Sound Understanding; MC= Misconception; NU= Not Understanding; ER= Errors.

The final conception of students in the experimental class obtained from the results of the post-test is shown in Table 8.

Table 8 Final conceptions of experimental class and control class students

Question Item Number	**Conception Category Percentage (%)**							
	SU		**MC**		**NU**		**ER**	
	Ex	Con	Ex	Con	Ex	Con	Ex	Con
B1	72	81	3	0	26	17	0	3
B2	78	69	8	3	14	25	0	3
B3	61	44	19	22	19	17	0	17
B4	86	53	14	11	0	33	0	3
Average	74.3	61.8	11.0	12.5	14.8	23.0	0.0	6.5

Ex= Experiment; Con= Control; SU= Sound Understanding; MC= Misconception; NU= Not Understanding; ER= Errors.

Table 8 provides information regarding the average percentage for each conception category based on the post-test results of students in the experimental and control classes. The SU category averaged 74.3% for the experimental class and 61.8% for the control class. The MC category was 11% for the experimental and 12.5% for the control classes. The NU category comprised 14.8% of the experimental and 23% of the control classes. Additionally, the ER category was 0% for the experimental class and 6.5% for the control class. Thus, the largest average percentage in both classes was obtained for the SU category, specifically 74.3% in the experimental and 61.8% in the control classes. This indicated a significant increase of 71.3% in students' conceptual understanding after they had undergone treatment through Conceptual Change Model learning activities with a Computational Thinking approach. This was in line with research conducted by (Sari and Nasrudin, 2015), which stated that the conceptual change model required optimal conceptual changes in students so that a better understanding was obtained.

The process of altering students' conceptions through Conceptual Change Model learning with a Computational Thinking approach was assessed based on the categories derived from students' pre-test and post-test scores on each question item. These scores were then analyzed in conjunction with students' responses to the Conceptual Change Model with Computational Thinking Learning Kit and Practice Design (CCM-CT LKPD) for the experimental class and the CCM for the control class. In this research, the analyzed change in conception focused on transforming students' conceptions into a deeper understanding of the concept. An illustrative example of this process was outlined in the explanation for question number 1, representing the sub-concept of Pascal's Law, as depicted in the scheme shown in Figure 2.

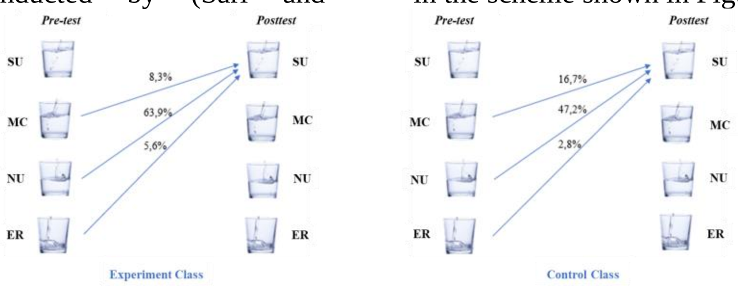


Figure 2 Changes in students' conceptions of question 1 of the concept of Pascal's Law

Based on Figure 2, the most common category of changes in conception occurred from the NU (Not Understand) category to the SU (Sound Understand) category in both the experimental class and the control class, as seen from the percentage calculation results obtained, namely 63.9% and 47.2%. This meant that more students experienced a change in conception from the NU category to the SU category in the experimental class than in the control class. The distribution of categories for changing students' conceptions in question number 1 was shown in Table 9.

Table 9 Distribution of students' conceptions categories in question number 1

Conception Change Category	Pre- → Post			Distribution of Students	
				Ex	Con
***No Charge* (NCh)**	 MC	→	 SU	26P, 31P, 32P.	06P, 11P, 14P, 17L, 30P, 34P.
***Acceptable Change* (ACh)**	 NU	→	 SU	01P, 02L, 03P, 04P, 05L, 07P, 08P, 09P, 10P, 12P, 15L, 16L, 17L, 18P, 20L, 22P, 23P, 25P, 28P, 29P, 33P, 35L, 36P.	02L, 03P, 04P, 07P, 09L, 12P, 15P, 16P, 21P, 23P, 24P, 27L, 29L, 31P, 32P, 33P, 36P.
	 ER	→	 SU	06P, 30P.	22P

The mode of changing students' conceptions in question 1 was the Acceptable Change (ACh) category from the NU to the SU category. Based on Table 9, 23 experimental class students experienced a change in conception from NU to SU, while in the control class, 17 students experienced a change in conception from NU to SU. The question related to sub-concept 1 of Pascal's Law is shown in Figure 3.

For example, 07P students in the experimental class and 33P students in the control class answered the questions and explanations incorrectly when working on the problems displayed in Figure 3 during the pre-test but properly during the post-test. Then, in the learning process, with the help of CCM-CT and CCM LKPD, phenomena related to Pascal's Law at the conceptual conflict stage were presented through practical activities. In the results of the LKPD analysis, students could explain the concept of Pascal's Law regarding the relationship between cross-sectional area and the forces acting on the cross-section, as shown in Figure 4.

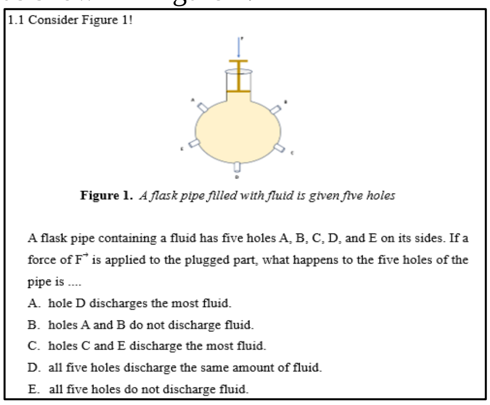
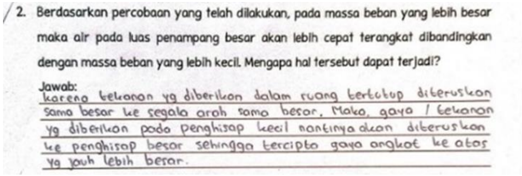

1.1 Consider Figure 1!

Figure 1. *A flask pipe filled with fluid is given five holes*

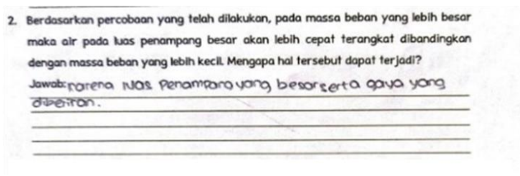
A flask pipe containing a fluid has five holes A, B, C, D, and E on its sides. If a force of F⁺ is applied to the plugged part, what happens to the five holes of the pipe is ....

A. hole D discharges the most fluid.
B. holes A and B do not discharge fluid.
C. holes C and E discharge the most fluid.
D. all five holes discharge the same amount of fluid.
E. all five holes do not discharge fluid.

Figure 3 Question number 1 sub-concept of Pascal's Law



Experiment Class



Control Class

Figure 4. Example of student LKPD answers

Figure 4 contained one of the students' questions and answers on the LKPD. The question presented was, "*Based on the experiment that has been done, at a larger mass of load, the water in a large cross-sectional area will be lifted faster than the smaller mass of load. Why does this happen?*". The experimental class students answered, "*This can happen because the pressure exerted in a closed space is transmitted equally in all directions. Then, the force/pressure exerted on the small sucker will be passed on to the large sucker to create a much greater upward force.*" Meanwhile, control class students answered, "This happens because of the large cross-sectional area and the force exerted." This showed that experimental class students could analyze the problem thoroughly compared to control class students.

Furthermore, in another problem presented in the Learning Kit and Practice Design (LKPD), after conducting the laboratory activity, students in both the experimental and control classes explained that "Pascal's Law states that in a closed fluid system, pressure will be transmitted in all directions with the same magnitude." This indicated that, after being given treatment through CCM-CT and CCM learning, students could reconstruct their conceptions to be correct in accordance with scientific principles, resulting in a change in conceptions from the NU (Not Understanding) category to the SU (Sound Understanding) category. If the percentage changes in conception were summed together, the experimental class had a bigger overall change in conception than the control class. This demonstrated that in question number one, which explored the concept of Pascal's Law after receiving treatment in learning, the experimental class students experienced more changes in their conception than the control class.

In addition to changes in the ACh change category, there were also changes in the NCh (+) category, namely, not experiencing changes in conception in the Sound Understanding (SU) category. For example, learners 26P of the experimental class and 17L of the control class answered the questions correctly during the pre-test and again during the post-test, indicating that the answers were correct and consistent with scientific principles.

In the experimental class, students demonstrated the ability to analyze discrepancies in the experimental results they obtained, particularly after being introduced to the concept in stage III of the CCM-CT LKPD. This was achieved through the persevering learning step, as shown in Figure 5.

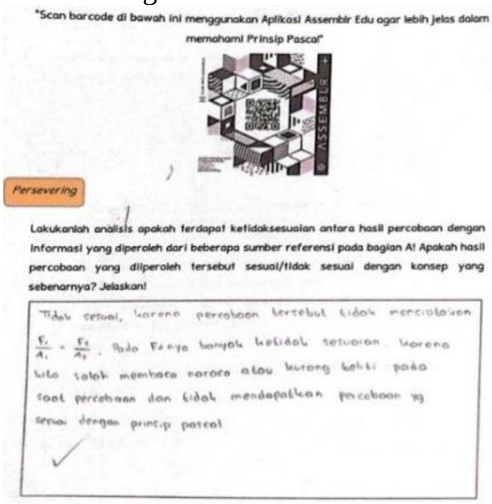


Figure 5 Example of student LKPD answers

Based on Figure 5, at the persevering stage of the CCM-CT LKPD, students reveal the differences between the concepts they obtained from the experiment results and the actual conceptual understanding, where in the experimental results, students stated that "*The pressure in section one is not the same as the pressure in section two, this is caused by several factors including errors in reading the experimental results on the spring balance.*" This indicated that the CCM-CT LKPD facilitated students to reveal discrepancies in concepts based on practical results with concepts that were in accordance with scientific principles. In the next stage, students could reconstruct their comprehension to comprehensively understand Pascal's Law. This preparation enabled students to tackle problems presented in the posttest with their acquired knowledge.

CONCLUSION

Based on the research findings, the data analysis results, and the presented discussion, it could be concluded that there was a disparity in students' understanding of Pascal's Law between those who underwent treatment using CCM-CT learning and those who received treatment through CCM learning. When assessed through the obtained N-Gain values, it was evident that the conceptual understanding of students who underwent CCM-CT learning exhibited relatively better results than those who underwent CCM learning alone. In future research, learning the CCM-CT approach could also be carried out to remediate students' misconceptions about Pascal's Law or other physics concepts.

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