Studies in Learning and Teaching (SiLeT)
Homepage: https://scie-journal.com/index.php/SiLeT
Email: silet@scie-journal.com

p-ISSN: 2722-399X; e-ISSN: 2722-1857
SiLeT, Vol. 4, No. 2, August 2023
Page 260-272

Discussion of Learning: Implementation and Effect on Critical Thinking Skills of Students in General Physics Courses

***T. Sunarti[1], M. Z. B. Amiruddin[1], Wasis[1], W. Setyarsih[1], M. N. R. Jauhariyah[1], A. Zainuddin[1]**
[1]Department of Physics, Faculty of Mathematics and Natural Science, Universitas Negeri Surabaya, Indonesia

Article Info

***Article history*:**

Received May 22, 2023
Revised June 29, 2023
Accepted July 7, 2023
Available Online August 31, 2023

***Keywords*:**

Critical thinking;
Discussion;
Learning;
Physics;

ABSTRACT

This study aims to determine the effect of applying the learning discussion model on students' critical thinking skills. This study uses a type of pre-experimental research with a research design, one group pretest-posttest design. The subjects of this research are students who program general physics courses from chemistry study program, biology study program, and mathematics study program. This research tested by giving pretest questions, treating discussion learning models, and posttest in general physics courses. The results of this study found that critical thinking skills students are the highest student (1) study program mathematics, (2) biology study program, and (3) chemistry study program. In addition, test results and learning each has a relationship with the other, proven by paired sample t-tests. That way, critical thinking skills are essential for students to master to compete in the era of technological development and the demands of the 21st century. Critical thinking skills are not seen from the department but from the ability of each individual in solving problems.

https://doi.org/10.46627/silet

INTRODUCTION

Physics is a science that is closely related to life. However, physics is a science that is considered difficult because it is famous for its formulas (Cuomo et al., 2022; Nasution, 2019; Rusli, 2011). In educational and non-educational programs at the faculties of mathematics and natural sciences, students in the first semester will certainly study primary physics material known as general physics. All majors in the faculties of mathematics and natural sciences study this general physics course. The learning that is carried out certainly has a specific model to get maximum results during the learning process. One learning model that can be used is discussion-based learning. Discussion learning enables students to solve problems, answer questions, understand knowledge, and make decisions (Ho et al., 2016; Nugroho, 2021; Yulianti & Sulistyawati, 2021). This study will use a discussion model of learning for chemistry, mathematics, and biology study program students. The hope is to increase and influence the level of students' critical thinking skills in general physics courses.

Ability of critical thinking is one of the learning outcomes for all students in the Faculty of Mathematics and Natural Science UNESA programming subject General Physics (Jatmiko et al., 2018; Widodo, 2022). This is stated in the Semester Learning Plan Subject General Physics, namely that after following subject general physics student must (1) have the ability to think critically and use appropriate concepts to qualitatively analyze problems and situations related to physics, (2) have the ability to use concepts of physics and mathematical methods are appropriate for get solution of quantitative problems in physics, (3) have the ability to collect and analyze data and compile reports coherent for their abilities, and (4) have the ability to communicate their findings both verbally and in writing. To achieve learning outcomes the general physics learning design

is integrated with theoretical lectures and practicum in the laboratory (Kua et al., 2021; Sriadhi et al., 2022).

In the learning process, chemistry, biology, mathematics, and even physics study programs, students also experience difficulties. This has become common place in studying physics because it is considered problematic. On the other hand, some students have a higher level of understanding than other students. Following what was conveyed by Dewi et al. (2019); Juwantara (2019); Zagoto et al. (2019), that individual differences certainly have different abilities. That way, it is no stranger to students who excel in physics courses. Chemistry, biology, and mathematics study program students also have several individuals who excel in general physics courses. So, it is crucial to know students' abilities by grouping them based on indicators of critical thinking.

The ability to think critically is crucial because it is a must-have skill mastered by students in the 21st century. Thinking critically requires practice and a sure way to be formed. Critical thinking can be formed by asking, classifying, and actively listening (Bean & Melzer, 2021; Lai, 2011; Polat & Aydin, 2020). The 21st-century skills, known as 6C, consist of critical thinking, creativity, character citizenship, collaboration, and communication (Evimalinda et al., 2022; Maneen, 2016; Nganga, 2019). Research conducted by Sulaiman et al. (2018) stated that students' critical thinking skills were still relatively low because there was a gap between theory and practice. In addition, research conducted by Aouaf et al. (2023) states that the gap in developing critical thinking skills is due to a lack of practice and a definite way to develop these abilities. The thing that can be done is to provide stages in solving problems so that students are directed in determining patterns of thinking to improve critical thinking skills.

The specific objective of this study was to determine the effect of implementing the discussion learning model on the level of critical thinking skills of chemistry, mathematics, and biology study program students. Based on the description above, solutions are offered to improve students' critical thinking skills, namely the discussion learning model and adding critical thinking indicators. The critical thinking indicators used in this study refer to Facione (1996), which consists of interpretation (understanding the meaning of something), inference (concluding something), analysis (understanding more deeply of information), explanation (explaining the meaning of one thing), and evaluation (assessing the credibility of the resulting conclusions). Through these indicators, it is possible to determine the level of students' critical thinking skills.

RESEARCH METHOD

This study uses a type of pre-experimental research. The research design used is one group pretest-posttest design. According to Sugiyono (2019), one group pretest-posttest design is a pre-experimental design consisting of a pretest, treatment, and posttest. The design can be seen in Figure 1.

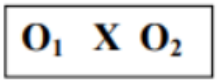


Figure 1. One group pretest-posttest design

(Sugiyono, 2019)

Information:

O_1 = Initial observation (pretest)

X = Treatment (using the learning discussion model)

O_2 = Final observation (posttest)

The subjects in this study consisted of 3 classes, namely, (1) 35 students from the chemistry study program, (2) 33 students from the mathematics study program, and (3) 29 students from the biology study program. The students who are the sample are new students who are programming general physics courses. The number of research samples is adjusted to the number of students in each class.

Then, initial observations were made to determine the level of students' critical thinking skills before learning. After that, treatment was carried out on students using a discussion learning model with indicators of critical thinking, according to Facione (1996). After learning, a second observation will be given to determine whether there are differences in the level of critical thinking skills before and after using the discussion learning model in general physics learning.

Through the N-gain test, it can be seen the increase in learning outcomes by using the following equation:

$$\text{N} - \text{gain} = \frac{\text{Score posttest} - \text{Score pretest}}{100 - \text{Score pretest}}$$

The results obtained will be interpreted according to the N-gain criteria, as shown in Table 1.

Table 1. Interpretation of value n-gain

N-gain Score	Category
g > 0,7	High
0,3 ≤ g ≤ 0,7	Medium
g < 0,3	Low

(Hake, 1999)

After that, the test results can be interpreted according to the criteria in Table 2 to find out students' critical thinking skills.

Table 2. Criteria for critical thinking skills

Critical Thinking Score	Category
81,25 < x ≤ 100	Very critical
62,50 < g ≤ 81,25	Critical
43,75 < x ≤ 62,50	Less critical
25,00 < x ≤ 43,75	Very less critical

(Setyowati & Subali, 2011)

RESULTS AND DISCUSSION

Improvement of Students' Critical Thinking Skills Based on N-gain

Critical thinking skills are no longer an option to be mastered but have become a requirement for students in the 21st century (Ahonen & Kinnunen, 2015; Malik, 2018; Soulé & Warrick, 2015). Critical thinking skills in chemistry, biology, and mathematics study programs in general physics courses can be identified after conducting tests and treatments on students. The results are shown in Table 3.

Table 3. The n-gain values

No	CSP			BSP			MSP		
	Pretest	Posttest	N-gain	Pretest	Posttest	N-gain	Pretest	Posttest	N-gain
1	16.67	60.00	0.43	22.22	93.33	0.71*	27.78	80.00	0.52
2	11.11	46.67	0.34	22.22	73.33	0.51	27.78	73.33	0.45
3	33.33	100.00	0.66*	16.67	66.67	0.50	22.22	100.00	0.78
4	38.89	80.00	0.41	5.56	40.00	0.34	27.78	86.67	0.59
5	16.67	53.33	0.37	22.22	60.00	0.38	16.67	66.67	0.50
6	11.11	46.67	0.35	11.11	46.67	0.35	11.11	46.67	0.35
7	16.67	53.33	0.37	11.11	46.67	0.35	22.22	73.33	0.51
8	27.78	60.00	0.32	33.33	93.33	0.60	16.67	66.67	0.50
9	11.11	53.33	0.42	22.22	66.67	0.44	22.22	100.00	0.78*
10	16.67	46.67	0.30	27.78	93.33	0.65	27.78	100.00	0.72
11	22.22	66.67	0.44	16.67	60.00	0.43	22.22	93.33	0.71
12	22.22	66.67	0.44	11.11	46.67	0.35	11.11	46.67	0.35
13	33.33	73.33	0.40	11.11	60.00	0.49	11.11	46.67	0.35
14	11.11	53.33	0.42	16.67	66.67	0.50	22.22	60.00	0.38
15	27.78	66.67	0.39	11.11	53.33	0.42	44.44	100.00	0.55

16	11.11	46.67	0.35	16.67	73.33	0.57	11.11	60.00	0.49
17	22.22	66.67	0.44	22.22	60.00	0.38	11.11	80.00	0.69
18	5.56	40.00	0.34	11.11	46.67	0.35	5.56	46.67	0.41
19	33.33	73.33	0.40	22.22	66.67	0.44	5.56	53.33	0.48
20	22.22	60.00	0.38	22.22	60.00	0.38	11.11	46.67	0.35
21	33.33	73.33	0.40	16.67	66.67	0.50	16.67	66.67	0.50
22	16.67	53.33	0.37	5.56	40.00	0.34	5.56	53.33	0.48
23	22.22	73.33	0.51	11.11	40.00	0.29	16.67	73.33	0.57
24	0.00	33.33	0.33	11.11	53.33	0.42	16.67	86.67	0.70
25	5.56	40.00	0.34	11.11	53.33	0.42	5.56	40.00	0.34
26	11.11	46.67	0.35	16.67	60.00	0.43	22.22	73.33	0.51
27	27.78	93.33	0.65	16.67	60.00	0.43	22.22	60.00	0.38
28	5.56	40.00	0.34	16.67	53.33	0.37	5.56	40.00	0.34
29	11.11	60.00	0.49	5.56	40.00	0.34	11.11	80.00	0.69
30	16.67	53.33	0.37	-	-	-	16.67	66.67	0.50
31	27.78	73.33	0.45	-	-	-	16.67	80.00	0.63
32	22.22	60.00	0.38	-	-	-	5.56	66.67	0.61
33	16.67	66.67	0.50	-	-	-	11.11	66.67	0.55
34	27.78	66.67	0.39	-	-	-	-	-	-
35	11.11	46.67	0.35	-	-	-	-	-	-

*= the highest N-gain, CSP: Chemistry Study Program, BSP: Biology Study Program, MSP: Mathematics Study Program

Table 3 presents the improvement of students' critical thinking skills based on the N-gain scores obtained by different means. The highest N-gain scores for chemistry, biology, and mathematics study programs were 0.6, 0.71, and 0.78, respectively. According to Erina and Kuswanto (2015); Nismalasari et al. (2016), the N-gain results can determine the increase in learning outcomes. In this case, the N-gain results can be used to see the increase in critical thinking skills. To see in more detail, the increase in students based on their categories can be seen in Table 4.

Table 4. Improved skills by category

Study Program	Number of Students	Category
Chemistry	0	High
	35	Medium
	0	Low
Biology	1	High
	27	Medium
	1	Low
Mathematics	5	High
	28	Medium
	0	Low

Table 4 presents the N-gain results based on the number of students in each study program. All chemistry students fall into the moderate category. Biology study program students who get low N-gain scores (1 student), medium (27 students), and high (1 student). None of the mathematics study program students received low n-gains, but there were medium (28 students) and high (5 students) n-gain scores. To see on average, the increase that occurred in the three study programs is presented in Table 5.

Table 5. The average increase in pretest, pottest, and n-gain

Data	Average Value Study Program		
	Chemistry	Biology	Mathematics
Pretest	19.05	16.09	16.67
Posttest	59.81	60.00	69.09
N-gain	0.41	0.44	0.52

Table 5 states students' critical thinking skills in terms of test results. In addition, the results of the N-gain test are used to find out the increase in student learning outcomes (Jatmiko et al., 2016; Khaldun, 2020; Neftyan et al., 2018). Based on the results of the N-gain test, the most significant increase occurred in chemistry, biology, and mathematics study program students with an average score of 0.42, 0.44, and 0.52, respectively, all of which were in the medium category. If viewed from the value obtained, then the highest increase in critical thinking skills is the mathematics study program.

Improvement of Critical Thinking Skills Based on Indicators

One way to measure the skills of a person or a group can be seen from the results before and after the treatment. In this case, critical thinking skills are measured on average from the number of students taking general physics courses. The measurement of critical thinking skills refers to indicators from Facione (1996). The results are presented in Table 6.

Table 6. Critical thinking skills students based on indicators

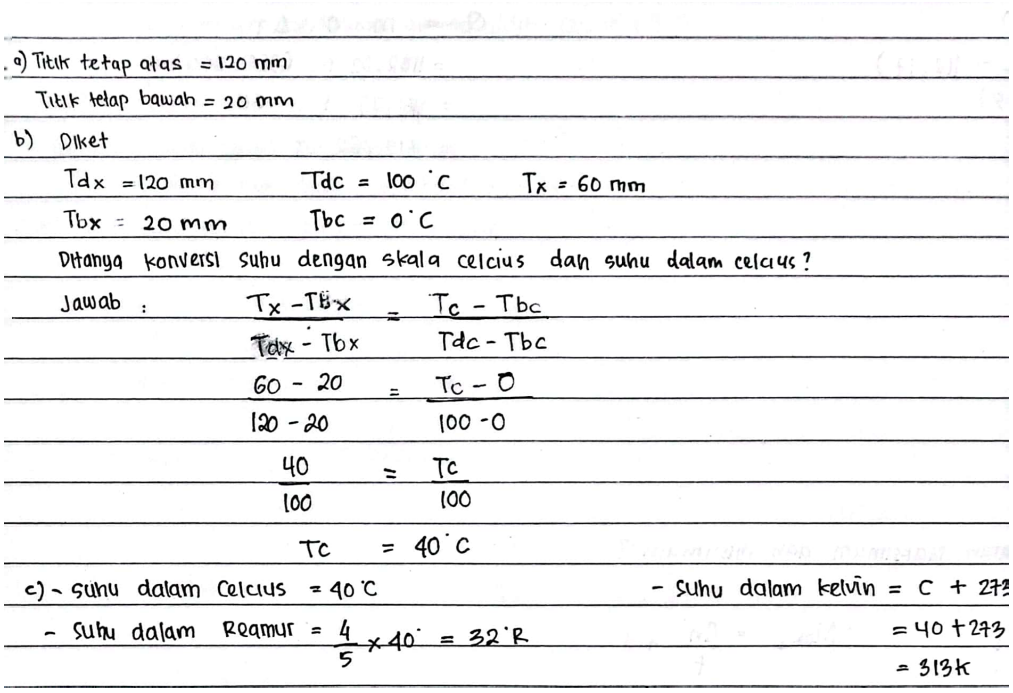
No	Indicator	Pretest			Posttest		
		CSP	BSP	MSP	CSP	BSP	MSP
1	Interpretation	30.48	32.18	34.34*	63.81	67.82	76.77*
2	Inference	8.57	20.69*	15.15	45.71	60.92*	59.60
3	Analysis	20.00	16.09	23.23*	53.33	60.92	62.63*
4	Explanation	25.71*	16.09	9.09	69.52	58.62	78.79*
5	Evaluation	29.52*	11.49	18.18	66.67	51.72	67.68*

*: highest, CSP: Chemistry Study Program, BSP: Biology Study Program, MSP: Mathematics Study Program

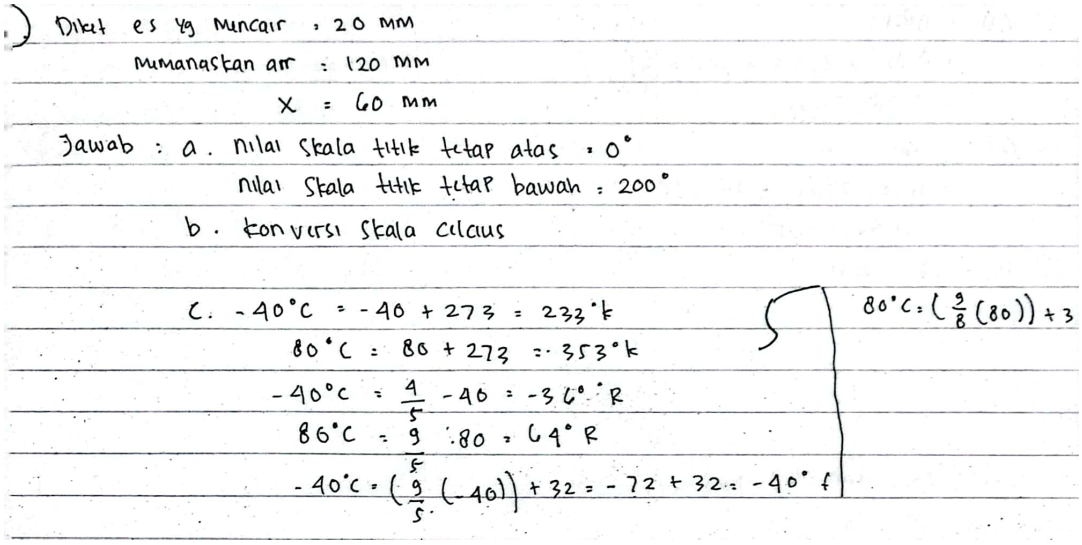
According to Amalia and Wahyuni (2020), Hartini and Martin (2020), and Rifâ (2018), learning physics to measure interpretation skills can be known, from that matter, asking for meaning or redefining existing information. Based on Table 6, the skills increased the most before and after using the model learning discussion. Interpretation indicators for results pretest and posttest, the highest was obtained from the mathematics study program at 34.34 and 76.77. This suggests that the skills of mathematics study program students are superior in interpreting the questions given to the women in general physics courses.

Furthermore, the inference indicators were dominated by biology study program students with pretest and posttest scores of 20.67 and 60.92, respectively. Inference is a skill by someone that identifies the information obtained. According to Larkin (2014) and Priyadi et al. (2018), inference in physics problems can be interpreted when someone can finish the given calculations. The next indicator is analysis, at this stage students plan a strategy to solve the questions given based on the skills possessed, such as determining the formula to be used or what equation is appropriate to solve the problem. Then, the explanation indicators on the pretest results were dominated by chemistry study program students with an acquisition score of 25.71. At the same time, the posttest results were dominated by a student mathematics study program with a score of 78.79. Students can explain and prove the correct answers to the questions are working on. After that, on the current evaluation indicator pretest, dominated by the chemistry study program, students with a score of 29.58, whereas on the posttest results, dominated by the mathematics study program, students a score of 67.68.

In working on the questions, some students take the test regularly, coherently, correctly, and wrongly. The forms of answers from both are shown in Figure 2.


a) Titik tetap atas = 120 mm
Titik tetap bawah = 20 mm
b) Diket
Tdx = 120 mm Tdc = 100 °C Tx = 60 mm
Tbx = 20 mm Tbc = 0 °C
Ditanya konversi suhu dengan skala celcius dan suhu dalam celcius?
Jawab : $\frac{Tx - Tbx}{Tdx - Tbx} = \frac{Tc - Tbc}{Tdc - Tbc}$
$\frac{60 - 20}{120 - 20} = \frac{Tc - 0}{100 - 0}$
$\frac{40}{100} = \frac{Tc}{100}$
Tc = 40 °C
c) - Suhu dalam Celcius = 40 °C
- Suhu dalam Reamur = $\frac{4}{5} \times 40 = 32$ °R
- Suhu dalam kelvin = C + 273
= 40 + 273
= 313k

a) Correct answer

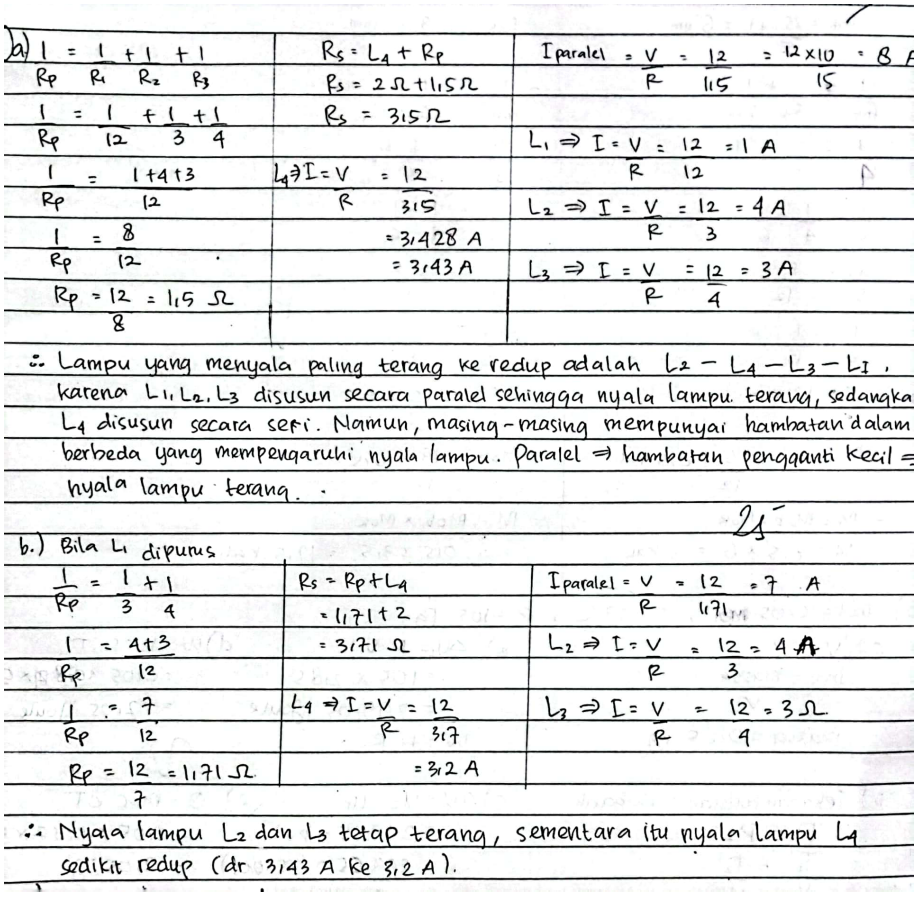

Diket es yg mencair : 20 mm
Rumanastan air : 120 mm
X : 60 mm
Jawab : a. nilai skala titik tetap atas : 0°
nilai skala titik tetap bawah : 200°
b. konversi skala celcius
c. -40°C = -40 + 273 = 233°k
80°C = 80 + 273 = 353°k
-40°C = $\frac{4}{5}$ -40 = -36° R
80°C = $\frac{9}{5}$ 80 = 64° R
-40°C = $\left(\frac{9}{5}(-40)\right) + 32 = -72 + 32 = -40°$ f
80°C = $\left(\frac{9}{8}(80)\right) + 3$

b) Wrong answer

Figure 2. Results of student answers on temperature questions

Based on the answers to the questions in Figure 2, you can know that the two students explain sequentially, starting from being known, being asked, and being answered. In this question, discussing the material temperature in physics learning. The answers presented show the difference in the ways answered between the two students. That way, the answers obtained will also be different. There are differences in students' critical thinking skills from the five indicators discussed. Based on these results, it can identify critical thinking skills students are less critical, which is very critical of the results of the tests carried out.

In addition, in the student critical thinking skills test, the physics material tested is not only in one subchapter, but in accordance with the learning that has been done in general physics courses. The other forms of questions, namely on electrical material related to series circuits and parallel circuits, are presented in Figure 3.



a) $\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$; $R_s = L_4 + R_p$; $I_{paralel} = \frac{V}{R} = \frac{12}{1,15} = \frac{12 \times 10}{15} = 8$ A

$\frac{1}{R_p} = \frac{1}{12} + \frac{1}{3} + \frac{1}{4}$; $R_s = 2\,\Omega + 1,15\,\Omega$; $L_1 \Rightarrow I = \frac{V}{R} = \frac{12}{12} = 1$ A

$\frac{1}{R_p} = \frac{1+4+3}{12}$; $L_4 \Rightarrow I = \frac{V}{R} = \frac{12}{3,15}$; $R_s = 3,15\,\Omega$; $L_2 \Rightarrow I = \frac{V}{R} = \frac{12}{3} = 4$ A

$\frac{1}{R_p} = \frac{8}{12}$; $= 3,428$ A ; $= 3,43$ A ; $L_3 \Rightarrow I = \frac{V}{R} = \frac{12}{4} = 3$ A

$R_p = \frac{12}{8} = 1,5\,\Omega$

∴ Lampu yang menyala paling terang ke redup adalah $L_2 - L_4 - L_3 - L_1$, karena L_1, L_2, L_3 disusun secara paralel sehingga nyala lampu terang, sedangkan L_4 disusun secara seri. Namun, masing-masing mempunyai hambatan dalam berbeda yang mempengaruhi nyala lampu. Paralel ⇒ hambatan pengganti kecil = nyala lampu terang.

21

b.) Bila L_1 diputus

$\frac{1}{R_p} = \frac{1}{3} + \frac{1}{4}$; $R_s = R_p + L_4$; $I_{paralel} = \frac{V}{R} = \frac{12}{1,71} = 7$ A

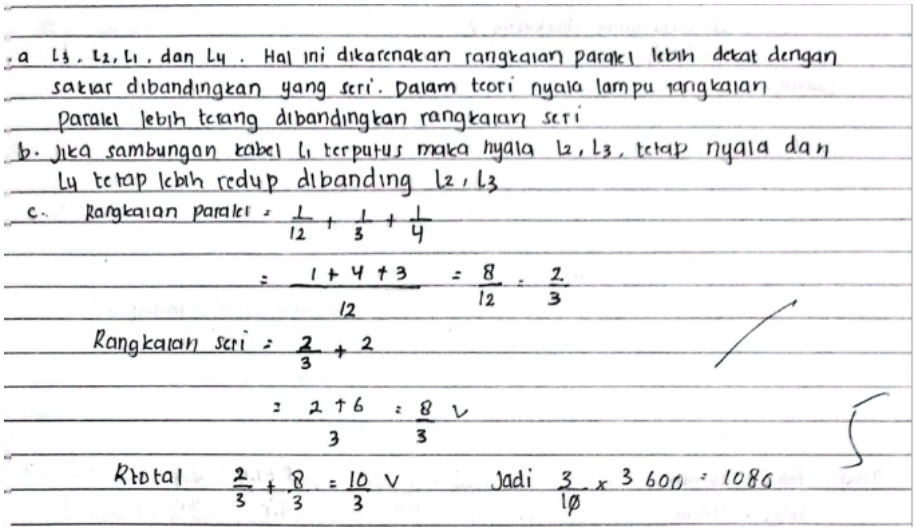
$\frac{1}{R_p} = \frac{4+3}{12}$; $= 1,71 + 2$; $L_2 \Rightarrow I = \frac{V}{R} = \frac{12}{3} = 4$ A

$\frac{1}{R_p} = \frac{7}{12}$; $= 3,71\,\Omega$; $L_4 \Rightarrow I = \frac{V}{R} = \frac{12}{3,7}$; $L_3 \Rightarrow I = \frac{V}{R} = \frac{12}{4} = 3\,\Omega$

$R_p = \frac{12}{7} = 1,71\,\Omega$; $= 3,2$ A

∴ Nyala lampu L_2 dan L_3 tetap terang, sementara itu nyala lampu L_4 sedikit redup (dr 3,43 A ke 3,2 A).

(a) Correct answer



a. L_3, L_2, L_1, dan L_4. Hal ini dikarenakan rangkaian paralel lebih dekat dengan sakelar dibandingkan yang seri. Dalam teori nyala lampu rangkaian paralel lebih terang dibandingkan rangkaian seri

b. Jika sambungan kabel L_1 terputus maka nyala L_2, L_3, tetap nyala dan L_4 tetap lebih redup dibanding L_2, L_3

c. Rangkaian paralel : $\frac{1}{12} + \frac{1}{3} + \frac{1}{4}$

$= \frac{1+4+3}{12} = \frac{8}{12} = \frac{2}{3}$

Rangkaian seri : $\frac{2}{3} + 2$

$= \frac{2+6}{3} = \frac{8}{3}$ V

Rtotal $\frac{2}{3} + \frac{8}{3} = \frac{10}{3}$ V Jadi $\frac{3}{10} \times 3600 = 1080$

(b) Wrong answer

Figure 3. Results of students' answers on electricity questions

Based on the answers in Figure 3, it can be seen that the forms of answers between students are very different. We can see this from the sequence of work done on answers a and b on the question. For the correct answer, the student presents calculations as well as proves by calculating the required results, while for the wrong answer, the student only conveys in writing his opinion without any support through the written results. This indicates that the skills possessed by students are definitely different. According to research results from Cahaya and Juandi (2021); Maguna et al. (2017); Santa et al. (2017); Syarifah and Usodo (2019) systematic and good answers have an influence on students' skill levels and critical thinking abilities.

Effect of Learning Discussion on Thinking Skills Critical Student

To determine the influence and relationship between the results and treatment can be traced using the test paired sample t-test (George & Mallery, 2021; Kim, 2015). The test results will show a connection between the pretest and posttest results and the relationships between treatment discussion learning enhancement results of critical thinking skills. To find out if there is a relationship between pretest and posttest, then a hypothesis is made as follows:

Ho = Data pretest and posttest interconnected

Ha = Data pretest and posttest unrelated

If the SPSS significance value < α (0.05), Ho is accepted, and Ha is rejected.

If the SPSS significance value > α (0.05), Ho is rejected, and Ha is accepted.

Table 7. Relationship between pretest and post-test

Paired Samples Correlations				
		Number of Students	Correlation	Sig.
Pair 1	Chemistry Study Program	35	0.870	0.000
Pair 2	Biology Study Program	29	0.862	0.000
Pair 3	Mathematics Study Program	33	0.725	0.000

Based on the relationships presented in Table 7, can the correlation be seen between the pretest and posttest from each product. The chemistry study program has a value correlation the biggest, followed by the biology and mathematics study program following the data presented above. Based on the results of the hypothesis mentioned, the significance value of the three study programs (sig.) 0.000 <0.005, it can be concluded that there is a relationship between the pretest and posttest, so Ho is accepted, and Ha is rejected (Risdianto et al., 2023). After that, to know the influence of the learning process learning discussion model, it can be seen from the results pretest and posttest, with hypotheses like the following.

Ho = There is an influence of the use of discussion model learning

Ha = There is no influence of the use learning discussion model

If the SPSS significance value < α (0.05), Ho is accepted and Ha is rejected.

If the SPSS significance value > α (0.05), Ho is rejected and Ha is accepted.

Table 8. The effect of learning discussions on learning outcomes student

Paired Samples Test									
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	Chemistry Study Program	-40.76143	8.06576	1.36336	-43.53211	-37.99074	-29.898	34	0.000
Pair 2	Biology Study Program	-43.90759	9.93995	1.84580	-47.68854	-40.12663	-23.788	28	0.000
Pair 3	Mathematics Study Program	-52.42394	13.25621	2.30761	-57.12439	-47.72349	-22.718	32	0.000

Based on the results in Table 8, it is known that the significant value of sig. (2-tailed) is 0.00 < 0.05. That way, Ho is accepted, and Ha is rejected. It states that learning using the learning discussion model impacts or influences critical thinking skills. According to Santoso (2019), decision-making refers to the significance value (sig.). In addition, from the mean value it can also be traced to an increase in the average pretest and posttest results. This is in line with what is stated by Afifah and Mudzakir (2022) and Ramadhani et al. (2019), the increase in learning outcomes can also be analyzed from the results of the average value obtained based on the SPSS test results. The minus sign on this value has no effect, it just states the magnitude of the change that has occurred and has no other purpose.

LIMITATION

There are limitations in this research, namely, (1) this research only uses three student classes as a research sample, (2) the students who are the sample are only taken from pure study programs, and (3) the material tested is general physics material for new students.

CONCLUSION

Critical thinking skills are critical to be mastered by students in general because they can help understand processes and daily activities. Based on the results of the analysis and research findings, the discussion learning model provides an increase in students' critical thinking skills in general physics courses. In addition, mathematics study program students dominate critical thinking skills based on the indicators tested.

This research implies that the discussion learning model can improve critical thinking skills. This research can be a source of literature to improve students' critical thinking skills on the material being tested. Applying the learning discussion model in general physics courses can be an alternative measurement of students' critical thinking skills in the faculties of mathematics and natural sciences.

The hope for further research is to apply model of discussion learning to compulsory subjects for each department to become a provision for students and lecturers in determining the family to be studied further. In addition, it is necessary to develop student worksheets to become a forum for determining students' critical thinking skills and as a supporting medium for implementing discussion learning models.

REFERENCES

Afifah, S., Mudzakir, A., & Nandiyanto, A. B. D. (2022). How to calculate paired sample t-test using SPSS software: From step-by-step processing for users to the practical examples in the analysis of the effect of application anti-fire bamboo teaching materials on student learning outcomes. *Indonesian Journal of Teaching in Science, 2*(1), 81-92. https://doi.org/10.17509/ijotis.v2i1.45895

Ahonen, A. K., & Kinnunen, P. (2015). How do students value the importance of twenty-first century skills?. *Scandinavian Journal of Educational Research, 59*(4), 395-412. https://doi.org/10.1080/00313831.2014.904423

Sulaiman, M. A. A., Swanto, S., & Din, W. A. (2018). Theory-practice gaps in developing critical thinking: Insights from a pedagogical study in Omani context. *Arab World English Journal (AWEJ), 9*(3), 258-281. https://dx.doi.org/10.24093/awej/vol9no3.18

Amalia, R. F., & Wahyuni, S. (2020). Analisis konten high order thinking skills (HOTS) soal fisika SBMPTN Tahun 2018 [Content analysis of high order thinking skills (HOTS) 2018 SBMPTN physics questions]. *UPEJ Unnes Physics Education Journal, 9*(1), 89-95. https://doi.org/10.15294/upej.v9i1.38285

Aouaf, S., Azzouzi, L., & Housni, H. (2023). Perceived barriers to critical thinking development: The student's view. *International Journal of Linguistics, Literature and Translation, 6*(2), 63-69. https://doi.org/10.32996/ijllt.2023.6.2.10

Bean, J. C., & Melzer, D. (2021). *Engaging ideas: The professor's guide to integrating writing, critical thinking, and active learning in the classroom*. John Wiley & Sons.

Cahya, E., & Juandi, D. (2021). Students' critical thinking skills in solving mathematical problems; a systematic procedure of grounded theory study. *International Journal of Instruction, 14*(4), 529-548. https://doi.org/10.29333/iji.2021.14431a

Cuomo, S., Di Cola, V. S., Giampaolo, F., Rozza, G., Raissi, M., & Piccialli, F. (2022). Scientific machine learning through physics–informed neural networks: Where we are and what's next. *Journal of Scientific Computing, 92*(3), 88. https://doi.org/10.1007/s10915-022-01939-z

Dewi, A. C., Hapidin, H., & Akbar, Z. (2019). Pengaruh model pembelajaran dan kemampuan berpikir kritis terhadap pemahaman sains fisik [The influence of learning models and critical thinking skills on understanding physical science]. *Jurnal Obsesi: Jurnal Pendidikan Anak Usia Dini, 3*(1), 18-29. https://doi.org/10.31004/obsesi.v3i1.136

Erina, R., & Kuswanto, H. (2015). Pengaruh model pembelajaran instad terhadap keterampilan proses sains dan hasil belajar kognitif fisika di SMA [The effect of the instad learning model

on science process skills and physics cognitive learning outcomes in high school]. *Jurnal Inovasi Pendidikan IPA, 1*(2), 202-211. https://doi.org/10.21831/jipi.v1i2.7507

Evimalinda, R., Situmorang, E. L., Butarbutar, R. D., & Ditakristi, A. H. V. (2022). The role of christian religious education teachers in building student's 6c skills in the era 4.0. *International Conference on Theology, Humanities, and Christian Education* (ICONTHCE 2021), 192-196. https://doi.org/10.2991/assehr.k.220702.044

Facione, N. C., & Facione, P. A. (1996). Externalizing critical thinking in knowledge development and clinical judgment. *Nursing Outlook, 44*(3), 129-136. https://doi.org/10.1016/S0029-6554(06)80005-9

George, D., & Mallery, P. (2021). *IBM SPSS statistics 27 step by step: A simple guide and reference.* Routledge. https://doi.org/10.4324/9781003205333

Hake, R. R. (1999). American educational research association's Division d, measurement, and research methodology: Analyzing change/gain scores. *Woodland Hills*.

Hartini, T. I., & Martin, M. (2020). Pengembangan instrumen soal HOTS (High Order Thinking Skill) pada mata kuliah fisika dasar 1 [Instrumental development of HOTS (High Order Thinking Skill) questions in basic physics 1 courses]. *JPF (Jurnal Pendidikan Fisika) Universitas Islam Negeri Alauddin Makassar, 8(*1), 18-21. https://doi.org/10.24252/jpf.v8i1.11687

Ho, V. T., Nakamori, Y., Ho, T. B., & Lim, C. P. (2016). Blended learning model on hands-on approach for in-service secondary school teachers: Combination of E-learning and face-to-face discussion. *Education and Information Technologies, 21*, 185–208. https://doi.org/10.1007/s10639-014-9315-y

Jatmiko, B., Prahani, B. K., Munasir, S., Wicaksono, I., Erlina, N., & Pandiangan, P. (2018). The comparison of OR-IPA teaching model and problem-based learning model effectiveness to improve critical thinking skills of pre-service physics teachers. *Journal of Baltic Science Education, 17*(2), 300. https://doi.org/10.33225/jbse/18.17.300

Jatmiko, B., Widodo, W., Martini, B., Wicaksono, I., & Pandiangan, P. (2016). Effectiveness of the INQF-based learning on a general physics for improving student's learning outcomes. *Journal of Baltic Science Education, 15(*4), 441. https://doi.org/10.33225/jbse/16.15.441

Juwantara, R. A. (2019). Analisis teori perkembangan kognitif piaget pada tahap anak usia operasional konkret 7-12 tahun dalam pembelajaran Matematika [Analysis of Piaget's theory of cognitive development in the stage of concrete operational age children 7-12 years in learning Mathematics]. *Jurnal Ilmiah Pendidikan Guru Madrasah Ibtidaiyah, 9(*1), 27-34. https://doi.org/10.18592/aladzkapgmi.v9i1.3011

Kim, T. K. (2015). T test as a parametric statistic. *Korean journal of anesthesiology, 68*(6), 540-546.

Kua, M. Y., Suparmi, N. W., & Laksana, D. N. L. (2021). Virtual physics laboratory with real world problem based on ngada local wisdom in basic physics practicum. *Journal of Education Technology, 5(*4), 520-530. https://doi.org/10.23887/jet.v5i4.40533

Khaldun, I. (2020). Influence of the contextual teaching and learning model against student learning outcome. *Journal of Physics: Conference Series*, *1460*(1), 012128. https://doi.org/10.1088/1742-6596/1460/1/012128

Lai, E. R. (2011). Critical thinking: A literature review. *Pearson's Research Reports, 6*(1), 40–41.

Larkin, J. H. (2014). The role of problem representation in physics. In D. Gentner & A. L. Stevens (Eds.), *Mental models* (pp. 83-106). Psychology Press. https://doi.org/10.4324/9781315802725-9

Maguna, A., Darsikin, D., & Pasaribu, M. (2017). Kemampuan berpikir kritis mahasiswa calon guru pada materi kelistrikan (Studi deskriptif pada mahasiswa program studi pendidikan fisika Universitas Tadulako Tahun Angkatan 2014) [Critical thinking ability of prospective teacher students in electricity material (Descriptive study on students of the physics education study program at Tadulako University Class of 2014]. *JPFT (Jurnal Pendidikan Fisika Tadulako Online), 4*(3), 42-51. https://doi.org/10.22487/j25805924.2016.v4.i3.6222

Malik, R. S. (2018). Educational challenges in the 21st century and sustainable development. *Journal of Sustainable Development Education and Research, 2*(1), 9–20. https://doi.org/10.17509/jsder.v2i1.12266

Maneen, C. A. (2016). *A case study of arts integration practices in developing the 21st-century skills of critical thinking, creativity, communication, and collaboration*. Gardner-Webb University.

Nasution, S. W. R. (2019). Pengaruh penguasaan pengukuran terhadap hasil belajar fisika siswa pada materi besaran dan satuan [The influence of measurement mastery on students' physics learning outcomes in the matter of quantities and units]. *Jurnal Education and Development, 7*(4), 175-175. https://doi.org/10.37081/ed.v7i4.1392

Neftyan, C. C. A., Suyanto, E., & Suyatna, A. (2018). The influence of learning using contextual teaching and learning approach to physics learning outcomes of high school students. *International Journal of Advanced Engineering, Management and Science (IJAEMS), 4*(6), 446-450. https://doi.org/10.22161/ijaems.4.6.3

Nganga, L. (2019). Preservice teacher perceptions of teaching for global mindedness and social justice: Using the 4Cs (Collaboration, Critical thinking, Creativity and Communication) in teacher education. *Journal of Social Studies Education Research, 10*(4), 26–57.

Nismalasari, N., Santiani, S., & Rohmadi, M. (2016). Penerapan model pembelajaran learning cycle terhadap keterampilan proses sains dan hasil belajar siswa pada pokok bahasan getaran harmonis [Application of the learning cycle learning model to science process skills and student learning outcomes on the subject of harmonic vibrations]. *Edu Sains: Jurnal Pendidikan Sains dan Matematika, 4*(2), 2338-4387. https://doi.org/10.23971/eds.v4i2.511

Nugroho, W. (2021). Pendekatan problem-based learning model diskusi kelompok berbantuan video youtube untuk meningkatkan aktivitas dan hasil belajar statistika [The problem -based learning approach is a group discussion model assisted by YouTube videos to increase statistics learning activities and results]. *Jurnal Pendidikan Matematika (Kudus), 4*(2), 211-226. https://doi.org/10.21043/jmtk.v4i2.12259

Polat, Ö., & Aydın, E. (2020). The effect of mind mapping on young children's critical thinking skills. *Thinking Skills and Creativity, 38*, 100743. https://doi.org/10.1016/j.tsc.2020.100743

Priyadi, R., Mustajab, A., Tatsar, M. Z., & Kusairi, S. (2018). Analisis kemampuan berpikir kritis siswa SMA kelas X MIPA dalam pembelajaran fisika [Analysis of critical thinking skills of class X MIPA senior high school students in learning physics]. *JPFT (Jurnal Pendidikan Fisika Tadulako Online), 6*(1), 53-55. https://doi.org/10.22487/j25805924.2018.v6.i1.10020

Ramadhani, R., Rofiqul, U. M. A. M., Abdurrahman, A., & Syazali, M. (2019). The effect of flipped-problem based learning model integrated with LMS-google classroom for senior high school students. *Journal for the Education of Gifted Young Scientists, 7*(2), 137-158. https://doi.org/10.17478/jegys.548350

Rifâ, A., Serevina, V., & Delina, M. (2018). The development of High Order Thinking Skills (HOTS) assessment instruments for temperature and heat learning. *Jurnal Penelitian & Pengembangan Pendidikan Fisika, 4*(1), 19-26. https://doi.org/10.21009/1.04103

Risdianto, E., Masito, F., Yustisia, N., Macariola, J. S., Fathurrochman, I., & Yunita, W. (2023, March). The effectiveness of augmented reality (AR)-based blended learning models to increase the creativity of prospective educators. *Mathematics and Science Education International Seminar 2021 (MASEIS 2021)*, 71-82. https://doi.org/10.2991/978-2-38476-012-1_11

Rusli, A., & Waldrip, B. (2011). Implementasi pembelajaran berbasis multi representasi untuk peningkatan penguasaan konsep fisika kuantum [Implementation of multi-representation-based learning to increase mastery of quantum physics concepts]. *Jurnal Cakrawala Pendidikan, 1*(1), 30-45. https://doi.org/10.21831/cp.v1i1.4189

Santoso, S. (2019). *Mahir statistik parametrik* [Proficient in parametric statistics]. Elex Media Komputindo.

Santa Anugrahaini, U., Nugroho, S. E., & Yulianto, A. (2017). Analisis kemampuan berpikir kritis dan kreatif pada penyusunan laporan praktikum Fisika Dasar [Analysis of critical and creative thinking skills in the preparation of Basic Physics practicum reports]. *Physics Communication, 1*(1), 49-59. https://doi.org/10.15294/physcomm.v1i1.8980

Setyowati, A., & Subali, B. (2011). Implementasi pendekatan konflik kognitif dalam pembelajaran fisika untuk menumbuhkan kemampuan berpikir kritis siswa SMP kelas VIII

[Implementation of the cognitive conflict approach in learning physics to foster critical thinking skills for class VIII junior high school students]. *Jurnal Pendidikan Fisika Indonesia, 7*(2), 89-96. https://doi.org/10.15294/jpfi.v7i2.1078

Soulé, H., & Warrick, T. (2015). Defining 21st-century readiness for all students: What we know and how to get there. *Psychology of Aesthetics, Creativity, and the Arts, 9*(2), 178. https://doi.org/10.1037/aca0000017

Sugiyono (2019). *Metode penelitian pendidikan (kuantitatif, kualitatif, kombinasi, R&D, dan penelitian pendidikan)* [Educational research methods (quantitative, qualitative, combination, R&D and educational research)]. Alfabeta

Sriadhi, S., Hamid, A., & Restu, R. (2022). Web-based virtual laboratory development for basic practicums in science and technology. *TEM Journal, 11*(1), 396. https://doi.org/10.18421/TEM111-50

Syarifah, T. J., & Usodo, B. (2019, July). Student's critical thinking ability with higher order thinking skills (HOTS) question based on self-efficacy. *Journal of Physics: Conference Series*, *1265*(1), 012013. https://doi.org/10.1088/1742-6596/1265/1/012013

Widodo, W. (2022). Online flipped classroom: developing postgraduate science education students' critical thinking skills. *Journal of Science Learning, 5*(2), 469-477. https://doi.org/10.17509/jsl.v5i3.43107

Yulianti, T., & Sulistyawati, A. (2021). Online focus group discussion (OFGD) model design in learning. *Proceedings of the 2nd International Conference on Progressive Education, ICOPE 2020*. https://doi.org/10.4108/eai.16-10-2020.2305199

Zagoto, M. M., Yarni, N., & Dakhi, O. (2019). Perbedaan individu dari gaya belajarnya serta implikasinya dalam pembelajaran [Individual differences in learning styles and their implications for learning]. *Jurnal Review Pendidikan dan Pengajaran (JRPP), 2*(2), 259-265. https://doi.org/10.31004/jrpp.v2i2.481

Author (s):

*Titin Sunarti (Corresponding Author)
Department of Physics, Faculty of Mathematics and Natural Science,
Universitas Negeri Surabaya,
Jl. Ketintang, Surabaya 60231, Indonesia
Email: titinsunarti@unesa.ac.id

Mohd Zaidi Bin Amiruddin
Department of Physics, Faculty of Mathematics and Natural Science,
Universitas Negeri Surabaya,
Jl. Ketintang, Surabaya 60231, Indonesia
Email: mohdzaidi.19079@mhs.unesa.ac.id

Wasis
Department of Physics, Faculty of Mathematics and Natural Science,
Universitas Negeri Surabaya,
Jl. Ketintang, Surabaya 60231, Indonesia
Email: wasis@unesa.ac.id

Woro Setyarsih
Department of Physics, Faculty of Mathematics and Natural Science,
Universitas Negeri Surabaya,
Jl. Ketintang, Surabaya 60231, Indonesia
Email: worosetyarsih@unesa.ac.id

Mukhayyarotin Niswati Rodliyatul Jauhariyah
Department of Physics, Faculty of Mathematics and Natural Science,
Universitas Negeri Surabaya,
Jl. Ketintang, Surabaya 60231, Indonesia
Email: mukhayyarotinjauhariyah@unesa.ac.id

Abu Zainuddin
Department of Physics, Faculty of Mathematics and Natural Science,
Universitas Negeri Surabaya,
Jl. Ketintang, Surabaya 60231, Indonesia
Email: abuzainudin@unesa.ac.id