

Analysis of Physics Education Students' Difficulties in Electricity and Magnetic Concepts in The Covid-19 Pandemic

Amiruddin Kade*, Supriyatman, Darsikin, Muhammad Zaky

Physics Education Study Program FKIP Universitas Tadulako Palu, Indonesia

*Email: puangamir@yahoo.com

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Abstract. This research is based on the behavior of students who are confused about explaining a natural phenomenon when taking electricity and magnetism courses. The covid-19 pandemic, which requires online courses, adds to the problems in improving the quality of learning in electricity and magnetism courses. As prospective teachers, physics education students with low concept mastery are certainly very concerned because they will teach it to their students. So this research aims to identify difficulties and recommendations for learning electricity and magnetism. The qualitative descriptive method is used to obtain a description of the problem, and obtain recommendations for effective and efficient learning. Learning is done online through zoom meetings and LMS.fkip.untad.ac.id. Data was collected by testing the mastery of the concept of electricity and magnetism. The test was given online to 40 students and interviews with 5 students as respondents. The results showed that the biggest difficulty of students in applying the concept of the potential vector was about 70%, analysis on the application of Ampere's law was about 47.5%, applying the concept of the field in a cylinder about 30%, and applying the Biot-Savart law was about 25%. It can be concluded that there are still many students who have difficulty mastering the concepts of electricity and magnetism after participating in online learning.

Keywords: electricity and magnetism concept, mastery of concepts, student difficulties

Introduction

The concept is an abstract idea that allows someone to classify or classify objects or events that are examples and not examples of the idea (Fajar et al., 2019). In studying physics, students must understand concepts and be able to apply them in problem solving activities to achieve learning success. The achievement of learning objectives can be used to determine how effective instruction has been. According to Murdani (2020), physics as a basic science has characteristics that include the form of science consisting of facts, concepts, principles, laws, postulates, and scientific theories and methodologies. Physics is a science that is formed through standard procedures or commonly referred to as the scientific method (Hestenes, 1987). Mastery of physics concepts is a competency of learning materials about students' understanding, knowing, applying, analyzing,

evaluating, creating, and making scientific observations (Wicaksono et al., 2020; Cookson & Stirk, 2019; Hartini et al., 2019).

The physics education student's difficulties can be interpreted as a condition in the instructional process which is marked by the presence of certain obstacles to obtaining learning outcomes. The obstacles that arise may be realized and may not be realized by the person who experiences them and they can be psychological, sociological, or physiologically in the whole learning process (Januarifin, et al., 2018; Rosada, 2016). Each student has a different conception of the concept of a scientist. This causes difficulties for students in applying the concept (Aravind & McConnell, 2018; Olpak, et al., 2017) and visualization.

Based on observations of student physics education, they are still confused about the concepts they have. For example, students are still confused by the concept of force in electric and magnetic fields, especially if the interactions between the two are in a plane forming an angle. Another example, many students cannot determine the coordinates in a three-dimensional graph (x,y,z) and the physical meaning of the calculation results. That concepts have been studied since first semester 1 (in basic physics courses). In the concept of electricity, students understand that rubbing plastic will attract small papers, they also know Coulomb's law, if different charges will attract and if the same charge will repel. They can also explain that if electric and magnetic fields are vector quantities, they still calculate them in scalar form. They were also able to give examples of electric and magnetic events, but they were unable to explain the microscopic processes by which these events occurred. Those phenomena were surveyed by Karim et al. (2018).

Te covid-19 pandemic, lecturers' mush teaching online adds to the burden on lecturers and students in improving the quality of graduates. Teacher candidate students who have low mastery of the concept are certainly very concerned. Provision of the ability of prospective teachers in constructing the knowledge they have and implementing it into problem solving is very important. It is necessary to identify student difficulties as information that is indispensable in compiling an effective and efficient learning experience during the covid-19 pandemic according to student needs. The question is how difficult is it for prospective physics teacher students to master the concepts of electricity and magnetism? To provide an answer to this question, this study aims to show the difficulties of physics education students in studying electricity and magnetism.

Methods

This research is a qualitative research. The rationale for qualitative research is intended to achieve analytic generalizations rather than generalizing results to populations. Analytical generalization aims to reach certain conclusions or theories through a limited number of participants or sources of information.

In addition, the qualitative research methods are research methods based on the post-positivism philosophy, used to examine the condition of natural objects (as opposed to experiments) where the researcher is the key instrument, sampling of data sources is done by purposive and snowball, the collection technique is tri-angulation (combined), the data analysis is inductive or qualitative, and the results of qualitative research emphasize meaning rather than generalization. With this method, the researcher describes the data that has been obtained and analyzes it so that they can get a description of the difficulties of students in mastering the material of electric magnetism.

This research was carried out in the even semester, the 2020/2021 Academic Year starting from March 2021 to October 2021 at the Physics Education Study Program, FKIP UNTAD, the subject of electricity and magnetism. The subject of this research about 40

females and 3 Males, third year (fifth semester). They are also a respondent in this research.

This study used an open questionnaire and interview instruments. An open Questionnaire Is a type of questionnaire with a list of questions that allows respondents to write their opinion about the questions on the questionnaire sheet given by the researcher. An Interview is a measurement instrument or what is known as an oral questionnaire. It involves a process in which the researcher gathers information from the respondents through verbal interactions. A previous researcher will prepare a structured list of questions related to the research before meeting the respondents for their opinion on a matter.

The data analysis used with descriptions and interview notes which are sources of qualitative data is considered raw data. Raw data were evaluated by the content analysis method. The main purpose of content analysis is to find concepts and relationships that explain the data obtained. The content analysis method is used to identify data, unite similar data within the framework of certain concepts and themes and uncover truths that may be hidden in the data. For this purpose, raw data is coded.

Results and Discussion

Asynchronous online classes use a Moodle-based learning management system (LMS) as shown in Figure 1.



Figure 1. Example of components displayed by lms.fkipuntad.com page.

Student can access attendance, announcement, lesson plan, assignment, and all about learning process.

LMS as an asynchronous online class contains semester learning plans (RPS), lecture contracts, attendance lists, and learning experiences for each meeting.

Pertemuan 11. Potensial Vektor Magnet

 **Tatap Maya**
 Mark as done
 Perkuliahan **tatap maya** setiap hari senin pukul 08.00 - 09.45 WITA Room 3

 **Materi Ajar**
 Mark as done
 Silahkan dipelajari materi berikut ya..

 **Tugas Potensial Magnetik**
 Mark as done
 Silahkan pelajari Buku griff hal. 234 - 238 kemudian kerjakan soal berikut

Problem 5.22 Find the magnetic vector potential of a finite segment of straight wire, carrying a current I . [Put the wire on the z axis, from z_1 to z_2 , and use Eq. 5.64.] Check that your answer is consistent with Eq. 5.35.

Problem 5.23 What current density would produce the vector potential, $\mathbf{A} = k\hat{\phi}$ (where k is a constant), in cylindrical coordinates?

Problem 5.24 If $\mathbf{B}$ is *uniform*, show that $\mathbf{A}(\mathbf{r}) = -\frac{1}{2}(\mathbf{r} \times \mathbf{B})$ works. That is, check that $\nabla \cdot \mathbf{A} = 0$ and $\nabla \times \mathbf{A} = \mathbf{B}$. Is this result unique, or are there other functions with the same divergence and curl?

Figure 2. examples of magnetic induction concept material displayed in LMS

The results of the students' concept mastery scores by category are shown in Table 1.

Table 1. Recapitulation of Student Concept Mastery

Number	Category	Students
1	hight	2
2	Middle	21
3	Low	14
4	Inactive	6

The categorization of mastery of the concept is determined based on the final score of students (mean scores of activities, assignments, midterm exams, and final semester exams). The high category with grades A- and A, the medium category with grades B and B+, and the low category is for grades B- and C. The non-active category of six students was obtained because the student did not have sufficient attendance, did not complete his assignment collection, and did not attend the exam.

Further analysis of the research subjects totaled 43 students consisting of 37 active students and 3 students who took the test but 70% of attendance was insufficient and 3 students were not active. The distribution of students who have difficulty in electric-magnetic courses is shown in Table 2.

Table 2. Recapitulation of difficulties experienced by students in the concept of magnetism.

No.	Difficulties	Material /Subject			
		Biot-Savart's law (concept 1)	Ampere's law application (concept 2)	The magnetic field in a cylinder (concept 3)	Potential Vector (concept 4)
1	Understanding	S28; S38	S28	S28	S11; S28; S35; S37; S38; S39
2	Applications	S11; S12; S17; S21; S27; S31; S34; S37; S39; S40	S31; S35	S8; S11; S12; S17; S18; S21; S27; S31; S34; S37; S39; S40	S2; S3; S4; S7; S8; S9 S10; S12; S13; S14; 15; S16; S20; S21; S22; S23; S24; S25; S26; S27; S29; S30; S31; S32; S33; S34; S36; S40
3	Analysis	S4; S9; S23	S2; S8; S9; S10; S11; S12; S15; S16; S21; S22; S26; S27; S30; S32; S34; S36; S37; S39; S40	S4; S5; S6; S7; S23	0
4	Not identification	S25; S35	S3; S4; S7; S17; S20; S23; S33; S38	S3; S35; S38	S17

Meanwhile, the results of the interviews related to the difficulties of students in mastering concepts, the obstacles faced, and the identification of difficult concepts to some students whom the researchers met on campus. The results of interviews with 5 students participating in the electric-magnetic course are shown in Table 3.

Table 3. Recapitulation of the results of interviews with respondents

No.	The Questions	General Answers
1.	What difficulties do you have in mastering the concept of magnetism?	It's hard to understand, sir. The lecturer's explanation is broken. Although there is material in the LMS it is difficult to understand. Better offline sir. Just a lot of work. If you can understand offline, sir, everything will be explained. But now the pandemic can't go offline. The advantage of being online is that you can study while doing other things and can be followed anywhere, sir
2.	What obstacles did you encounter in taking the electric magnet lecture?	Network and quota sir. It's hard to find a place with a good network. So the lecturer's explanation is not good to hear, especially if you send assignments, it takes a long time to upload them, sir.
3.	What concepts do you find difficult to understand?	All sir. It's all difficult... especially when it comes to calculations. Yes, maybe it's because I don't study much, sir.

Based on the results of the data analysis above, the mastery of concepts in the electric-magnetic course is in the moderate category of 21 students (49.0%) with a score range of 66 to 80. The high category with a score range of 81 to 100 is 2 students (4.6%). The low category consisted of 14 students (32.6%) with a score range of 0 to 65. The above score was obtained from the calculation of all student assignments and examinations to determine the final score of students. Table 2 shows that students' abilities vary and depend on the concept being solved (Lin & Singh, 2013).

In-depth analysis to identify difficult concepts experienced by students was carried out on the concept of magnetism. These concepts include:

1. Biot-Savart's law
2. Application of Ampere's Law
3. Magnetic field around the cylinder
4. Potential Vector

In Table 2 the number of research subjects listed is 40 students, while the course participants are 43 students. Three students are not active. The three students did not attend lectures but were registered as course participants. The cognitive domain of mastery of the concept of magnetism which is evaluated at the end of the semester exam obtained the following distribution:

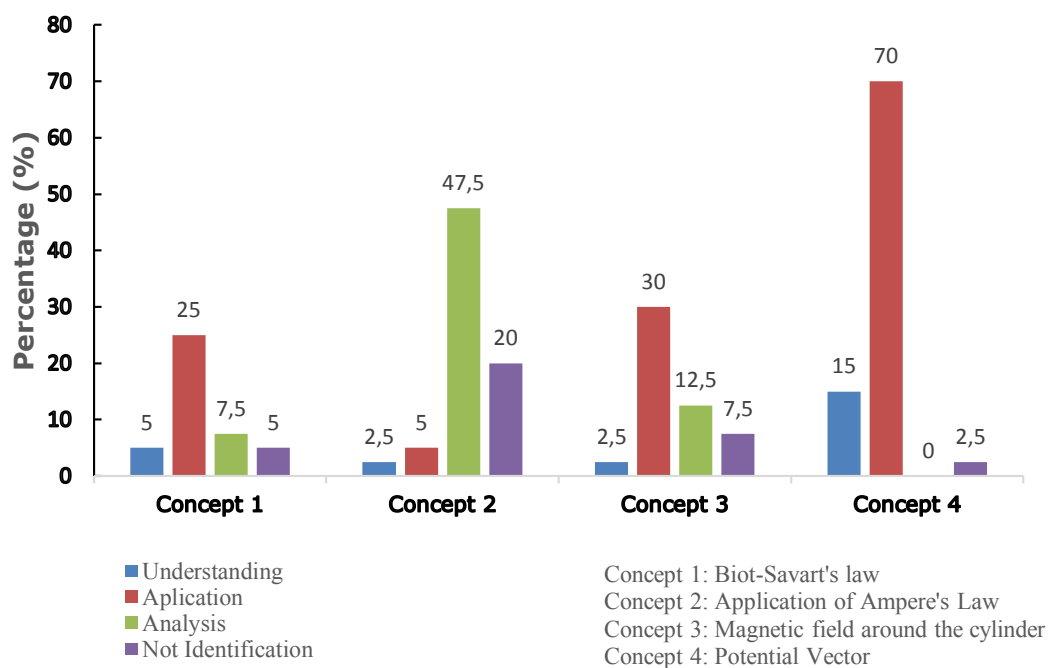


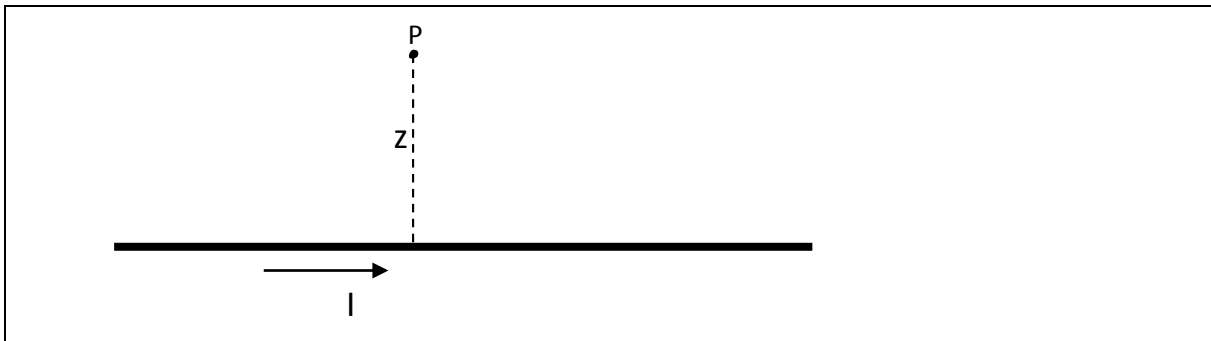
Figure 3. Graph of the percentage of students' difficulties with magnetism concept in the cognitive domain

Students' difficulties with the concept of Biot-Savart's law

In this concept, the students' biggest difficulty is applying the concept of Biot-Savart's law around a current-carrying wire, which is 25%. The questions given are in the form of questions as follows:

Question 1:

"Determine the magnetic field at point P as shown in the following figure using Biot-Savart's law and Ampere's law!"



One of the subjects in this group is S11. S11 understands the concept of the field around a current-carrying wire, understanding that the field strength is directly proportional to the current in the wire. However, S11 cannot use this concept to determine the magnitude and direction of the field strength that lies above the long wire. The answer for S11 is shown in Figure 4.

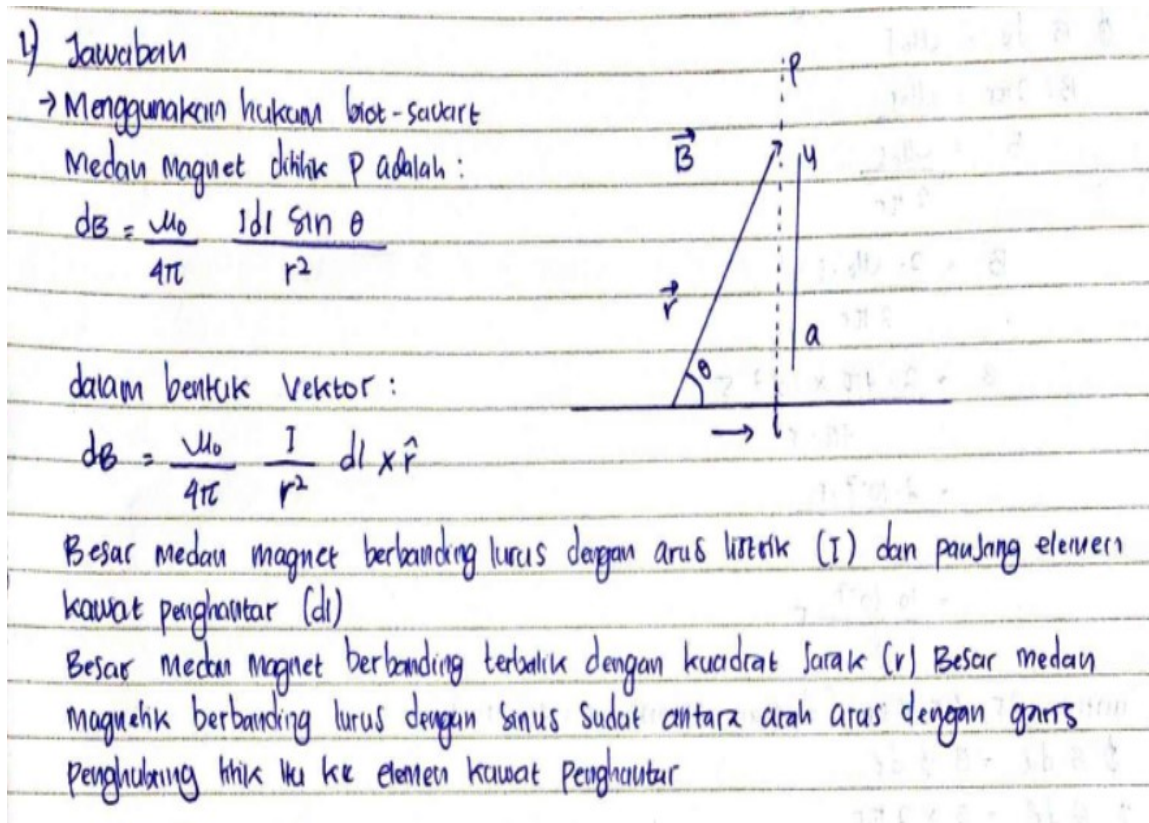


Figure 4. A snippet of S11's answer to question number 1.

The results of S11's answer (Figure 4) show that S11 already understands the concept of a magnetic field but cannot use it in solving problems.

Students' difficulties in applying the concept of Ampere's law

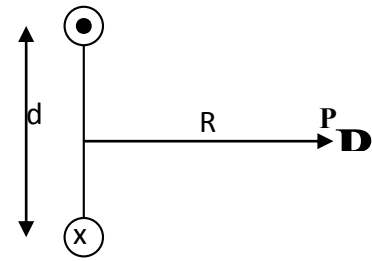
In this concept, the biggest difficulty for students is the difficulty in analyzing questions, which is 47.5%. The questions given are in the form of questions as follows:

Question 2:

"Two long wires at a distance d from each other carry currents I of equal magnitude and opposite in direction, as shown in the figure. Show that B at point P ,

$$B = \frac{2\mu_0 id}{\pi(4R^2 + d^2)} "$$

which is the same distance from the wires, is given by



One of the subjects in this group is S30. S30 understands the concept of the field around a current-carrying wire and understands the mathematical use of ampere's law, but it doesn't fit the problem given. The answer S30 is shown in Figure 5.

2. Jawab : $\oint B \cdot dr = \mu_0 \cdot I$
 $B \times 2\pi r = \mu_0 \cdot I$
 $B = \frac{\mu_0 \cdot I}{2\pi r}$
 $B = \frac{2\pi \mu_0 \cdot I}{4\pi \cdot r}$
 Sehingga : $B = \frac{2\mu_0 \cdot I \cdot d}{4\pi r (r^2 + d^2)}$
 $B = \frac{2\mu_0 \cdot I \cdot d}{4\pi (r^2 + d^2)}$

Figure 5. A snippet of S30's answer to question number 2.

The results of S30's answer (Figure 5) show that S30 did not analyze the field interaction due to the current flowing in wire 1 and wire 2. This analysis will guide S30 to find the magnitude and direction of the magnetic field at point P. The researcher concludes that S30 experiences difficulty using the concept to analyze problem number 2. The difficulty in solving problems on this concept is in line with research conducted by Yustiandi & Saepuzaman (2017) where students have difficulty in determining the direction of magnetic induction. The student also has difficulty to analysis the problem because their concept lack to link to other concepts (Nousiainen,et all, 2017).

Students' difficulties in the concept of a magnetic field in a cylinder

In this concept, the biggest difficulty for students is the difficulty in applying the concept, which is 30.0%. The questions given are in the form of questions as follows:

Question 3:

Determine the magnitude of the magnetic field inside and outside a hollow cylinder having an inner radius of $r=25$ mm and an outer radius of $R=50$ mm. The cylinder carries a current I of 5 A."

One of the subjects in this group is S40. S40 understands the concept of a magnetic field around a current-carrying wire and understands the mathematical use of ampere's law, but it doesn't fit the problem given. The answer to S40 is shown in Figure 6. S40 has difficulties in recognizing the representation of electric field lines compared to vector field plots, and algebraic notation (Rizkiyanti & Mansyur, 2021; Agnes M., et al, 2021).

* $25 < r < 50$

$$\oint B \cdot dl = B \oint dl$$
$$\oint B \cdot dl = B \cdot 2\pi r$$
$$\oint B \cdot dl = \mu_0 I_{enc}$$
$$B \cdot 2\pi r = \mu_0 \cdot \frac{(b^2 - r^2)}{(b^2 - a^2)} \cdot I$$
$$B = \frac{\mu_0}{4\pi} \cdot 2 \cdot \frac{(b^2 - r^2)}{(b^2 - a^2)} \cdot \frac{1}{r} \cdot I$$
$$B = 10^{-7} \cdot 2 \cdot \frac{(50 \cdot 10^{-1})^2 - (r^2)}{(50 \cdot 10^{-1})^2 - (5 \cdot 10^{-1})^2} \cdot \frac{5A}{r}$$
$$B = 2 \times 10^{-7} \cdot \frac{(50 \cdot 10^{-1})^2 - (r^2)}{(50 \cdot 10^{-1})^2 - (5 \cdot 10^{-1})^2} \cdot \frac{5A}{r} \text{ T}$$

* $r > 75$

$$\oint B \cdot dl = B \oint dl$$
$$\oint B \cdot dl = B \cdot 2\pi r$$

→ Jumlah arus yang dilingkupi lintasan amperes : $I_{enc} = 0$

maka $\oint B \cdot dl = \mu_0 I_{enc}$

$$B \cdot 2\pi r = \mu_0 \cdot 0$$
$$B = \frac{\mu_0 \cdot 0}{2\pi r}$$
$$B = 0$$

Figure 6. A snippet of S40's answer to question number 3.

The results of S40's answer above show that S40 has difficulty in applying the concepts it has. This difficulty is especially in the areas $0 < r < 25$ and $r > 50$. These two areas of the S40 are reversed in applying the concept. The researchers concluded that S40 had difficulty in applying the concept to solve problem number 3. The ability to apply knowledge (concepts) is important in helping students solve problems and is a basic element that supports students in science (Stehle & Peters-Burton, 2019) and can help students deal with new situations (Hu & Rebello, 2013). In this case, according to (Wrahatnolo & Munoto, 2018) students use mathematics and science to solve practical problems.

Students' difficulties in the concept of potential vectors

In this concept, the biggest difficulty for students is the difficulty in applying the concept, which is 70.0%. The questions given are in the form of questions as follows:

"Knowing the magnetic potential vectors: $A = x^2 y \hat{i} - 2xz \hat{j} + 2yz \hat{k}$. Determine the magnitude of the magnetic field!"

One of the subjects in this group is S10. S10 understands the concept of a magnetic field around a current-carrying wire and understands the mathematical use of ampere's law, but it doesn't fit the problem given. The answer to S10 is shown in Figure 7.

4. diketahui potensial vektor magnet $A = x^2y\hat{i} - 2xz\hat{j} + 2yz\hat{k}$. tentukan
 besar medan magnetnya!

Jawaban :

$$\vec{B} = -\nabla A = -F_x\hat{i} - F_y\hat{j} - F_z\hat{k}$$

$$F_x = (x^2y)\hat{i} - F_y(2xz)\hat{j} + (2yz)\hat{k}$$

$$= (x^2 - 2x) - y + 2y + (2 + 2)$$

$$= -x(2y + 2z)$$

Figure 7. S10's answer to question number 4. S10 has difficulty in mathematics to applying the concept of potential vectors (indicated by the red line curve).

The results of S10's answer above show that S10 has difficulty in applying the concept of the relationship between potential vectors and magnetic field strength. This difficulty is due to S10 not being able to apply the concept of derivatives in equations. This difficulty is marked by a circle in the snippet of S10's answer in Figure 7. The researcher concludes that S10 has difficulty in applying the concept to solve problem number 4. This finding is a result of (Hashish et al., 2020) students' persistent encountering difficulties in their understanding of analysis of potential vector problems (Table 2) or students lacking the use of mathematics (Protima, et al, 2020; Stehle & Peters-Burton, 2019)

Conclusion

The temporary conclusion from the results of the data analysis is that most of the student competencies are in the moderate category (21 students). Student activity in LMS is quite good although there is still a small number (6 students) who are not active. The identification results obtained the most difficulties experienced by students in the concept of potential vectors. That is, 70% of students have difficulty applying the concept of potential vectors in the competence to calculate potential vectors. The other concepts are Biot-Savart's law (25%), the application of Ampere's law (47.5%), and the magnetic field around a hollow cylinder (30%).

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