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Investigating Students' Problem-Solving Approach in the Concept of Electrostatic Force

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ABSTRACT

The purpose of the study was to investigate students' problem-solving approach in the concept of electrostatic force. The study was conducted from February until May in the second semester of the 2020/2021 academic year by using qualitative approach of case study design. The population of this study were all students of physics education study program at the Faculty of Teacher Training and Education of Cenderawasih University in Jayapura, Indonesia. A total of 10 students participated in the study. The data were collected through an essay test, interview, and Focus Group Discussion (FGD). Based on the result of data analysis, it is found that the students' approach was 50% categorized as plug and chug, 30% categorized memory-based approach, and 20% categorized no clear approach.

Keywords: *Electrostatic Force, Problem Solving Approach, Student.*

1. INTRODUCTION

This research is a preliminary study that investigates the approach used by students in solving problems related to the concept of electrostatic force. The concept of electrostatic forces is taught in the introductory physics course (PFIS 4216) in the second semester and the electricity and magnetism field (PFIS 4222) in the fifth semester. The electricity and magnetism course aims to strengthen the concepts of fundamental physics material that has been studied in the introductory physics courses. Electricity and magnetism lectures are abstract concepts and are full of mathematical formulations. This study is a new thing to do in the Physics Education Study Program, Faculty of Teacher Training and Education, Cenderawasih University.

The teaching and learning process that occurred during the COVID-19 pandemic took place online and offline. Based on preliminary data from a survey conducted to 16 students randomly regarding the evaluation of magnetic electricity lectures, it was reported that the quality of the lecture programs held was slightly above sufficient with an average score of 2.6. Several things need to be considered from the results of the initial survey. First, the provision of examples and the use of varied methods. Second, 50% of students said they were good while 58% of students stated that the provision of problem-solving exercises and the use of learning media was in the sufficient category.

Based on the results of the initial survey, it seems that students are still not equipped with problem-solving skills. Whereas problem-solving teaching is one of the important topics in physics education [1] and problem-solving is an important element in learning physics [2]. Therefore, physics education students should have sufficient opportunities to develop their problem-solving abilities. When they become teachers, one of their tasks is to guide students in learning to solve physics problems. Teaching how to solve problems is a teacher's activity. The teacher needs to challenge or motivate students to understand the problem, interest in solving the problem, use all of their knowledge to formulate strategies in solving the problem, implement the strategy, and evaluate solutions. Problem-solving is the main tool in learning in universities [3]. Learning must be able to run effectively and efficiently. Thus, students can apply their knowledge to solve the problems at hand [4].

The pilot study found the phenomena that occur in the Physics Education Study Program, Faculty of Teacher Training and Education, Cenderawasih University. It delivered this research to answer the question: What is the approach taken by physics education students in solving problems related to the concept of electrostatic

force? The results of this study were expected to contribute to improved learning and further research development, such as the development of teaching materials or the development of learning models.

In the field of physics education, research on problem-solving has been done by many previous researchers. Research on the approach used by students in solving problems with the main result is a hierarchical set of categories that describe the students' problem-solving approach in the context of introductory physics [5]. Research on the approach used by students in solving problems in the material of magnetic electricity and optical waves [6]. Research that examines behaviour and approaches in student solving [7]. The previous research focused on the approaches, strategies, and models used by grade 7th and 8th students in solving real-world problems. It used qualitative inquiry methods with a total of 116 students as respondents [8]. There was also research to see the performance of beginners (novice) and experts [9,10], and problem-solving skills on the concept of bullet motion (projectile motion concept) [11]. Several studies focused in the field of learning innovation [12,13,14,15,16] and the development of instruments to measure problem solving skills [17,18,19]. Then a study compared the problem-solving skills of men and women in senior high school students [20].

2. METHOD

This study uses a qualitative approach using a case study design [21], where this research looks for the meaning behind the phenomenon. Case studies have been widely applied by researchers in research in the field of physics education, including those that examine the epistemological framework of problem-solving [22] and problem-solving carried out by students on kinematics material [23]. This research was conducted from February until May in the second semester of the 2020/2021 academic year at the Physics Education Study Program, Faculty of Teacher Training and Education, Cenderawasih University.

The Physics Education Study Program curriculum provides introduction physics courses, which are taught in the first year and magnetic electricity, which is taught in the fifth semester. The total number of research participants was ten students. They were selected purposively by considering students who had passed introduction physics and electromagnetic electrification courses. The students were in the eighth semester. The characteristics of the study participants are shown in Table 1.

Table 1. Characteristics of participants of the study

Sex	Number	Age
Male	3	22-24
Female	7	
Total	10	

2.1. Data Collecting

Data were collected using a written test in the form of descriptions, semi-structured interviews, and focus group discussions (FGD). The researcher himself was the main instructor [23]. The test was made by the researcher and then validated by two experts. After getting input from experts, revisions and improvements were made. The blue print test was tested on students outside of the research participants. It can determine the readability aspect and how long the estimated time needed to work on it. The test consists of two items. The first question indicator determines the magnitude and direction of the total force on charged particles placed in the corners of the triangle. The second question indicator determines the magnitude and direction of the total force of charged particles placed in the corners of the longitude.

Data collection was carried out by giving a test first. Then, semi-structured interviews were carried out. The FGD was conducted to obtain supporting data as well as triangulation. During the research, the researchers made field notes.

2.1.1. Individual Interviews

Interviews were conducted individually with a semi-structured method using an interview guide prepared by the researcher with specific questions. The purpose of the interview was to explore the approaches used by students in solving problems related to the test results. The focus of the interview is what the initial ideas are and how students solve problems by referring to the key characters [5]. In addition, interviews were also intended to obtain additional data about students' understanding of concepts.

Interview activities were recorded using a tape recorder. The time required for the interview is not limited to each student and ends when the researcher feels that the data is sufficient, while the time duration is between 7-14 minutes with an average of 8 minutes. Re-interviews were conducted with five students to clarify unclear information. The interview stage begins with students reading the questions given in the previous written test, then followed by trigger questions by the researcher, for example, "what did you think about the first time you read the questions?" Based on the students' answers or explanations, the researcher then asks further questions with key questions to dig deeper until the data is considered adequate.

2.1.2. Forum Group Discussion (FGD)

The FGD was held after the interview was completed. Participants in this study had various abilities and it can be seen from their learning achievement so that a special strategy was applied in the implementation of the FGD. The FGD was conducted to clarify the findings that

emerged based on the written test and interview results. The time required for the FGD is approximately one hour. The FGD session was expected to be one way to collect and confirm data based on students' problem-solving approach to the concept of electrostatic force during the physics course in the classroom.

3. DATA ANALYSIS

To answer the research questions, based on the data collected by the data analysis process, it was qualitatively analyzed based on the four outcomes space of problem-solving. It was qualitatively analyzed based on the four outcome space of problem-solving by referring to the key characteristics as shown in table 2 [5], with the following steps: (1) analyzing each participant's written test answer quantitatively using problem-solving rubrics [24] and qualitatively, making descriptions, coding based on the characteristics of the problem-solving approach, making inferences, (2) making transcriptions of the recorded results called also protocols for each participant, analyzing protocols, interpreting, and making provisional conclusions (inferences); (3) reviewing FGD data and field notes; (4) compiling the unit of analysis based on the category of a problem-solving approach, synchronizing the results of the analysis and coding; and then (5) draw conclusion.

Table 2. Outcome space of students' approaches to problem solving

Category	Key characteristics
Scientific approach	● Qualitatively analyze the situation ● Plans and carries out solution in a systematic manner based on analysis ● Refers to concepts to guide the solution ● Evaluates to solution
Plug and chug: ○ Structured manner	● Qualitatively analyze the situation base on required formula ● Plan the solution based on the variables proceeds systematically ● Refers to concepts to guide the solution ● Evaluates to solution
○ Unstructured manner	● Analyze the situation based on required variable ● Proceeds by choosing formulas based on the variables in a trial-and-error manner ● Refers to concepts as variables ● Conducts no evaluation
Memory-based approach	● Analyze the situation based on required variable previous examples ● Proceeds by trying to "fit" the given variables to those examples ● Refers to concepts as variables ● Conducts no evaluation
No clear approach	● Analyze the situation based on the given variables ● Proceeds by trying to use the variables in a random way ● Refers to variables as terms ● Conducts no evaluation

4. RESULTS AND DISCUSSION

This research is a preliminary study to identify the problem-solving approach used by students on the concept of electrostatic force, which refers to the key characteristics [5]. Written tests, interviews, and FGDs were conducted to explore the problem-solving approaches used by students. Based on data analysis, the findings of this study indicate that there are variations in the approach used by students in solving problems, namely 50% in the plug and chug category, 30% in the memory-based approach category, 20% in the no clear approach category, and 0% in the scientific approach category such as shown in Table 3.

Table 3. Category of students' approach to problem solving

Category of problem solving	Student	
	In number	In percent
Scientifics approach	0	0
Plug and chug	5 (Structured manner = 3 and Unstructured manner = 2)	50
Memory-based approach	3	30
No clear approach	2	20

4.1. Plug and chug manner structured

The findings show that there are three people or 30% of students using a plug and chug structured approach. Students who are in the plug and chug structured manner category begin their problem solving by analyzing problems based on formulas and relating them to known information or variables, and their work is systematic. At the end of their work, they do an evaluation or proofread. The following is an example of a snippet of interviews conducted with students in the plug and chug structured manner student category.

Interviewer	:	Please read the first problem.
Student	:	Okay, sir [reading].
Interviewer	:	After you read the first problem, what was the first thing that came to your mind?
Student	:	It was in my mind that first, the equations of Coulomb's law came up.
Interviewer	:	What steps did you take to solve the problem?
Student	:	Write down what is known first, then what is asked. After that do the calculations. First, calculate the force F_{AB}, F_{AC}, then calculate the total force F by adding.
Interviewer	:	After you finish your work, what do you do?
Student	:	When I finish working and get the final answer, I usually look back at him, I double-check whether my calculations are correct or not, including the units used. Then when I am sure I move it or I write it on the answer sheet. Usually, when I do work, I use my claws first on another paper, sir.

4.2. Plug and chug manner unstructured

Two students are belonging to the plug and chug manner unstructured group or 20%. They use a problem approach by first identifying the variables needed to solve the problem, then choosing the formula to use. At the end of the solution, they do not do an evaluation. Interviews for students belonging to this category are presented as follows.

Interviewer	:	After you read the first problem, what was the first thing that came to your mind?
Student	:	What I am thinking about is changing your unit.
Interviewer	:	What are the steps to complete?
Student	:	Plugs what is known into the formula sir, then calculates sir.
Interviewer	:	After you get the answer, what do you do?
Student	:	No, sir, that's the answer.

4.3. Memory-based approach

The group of students belonging to the memory-based approach category is three people or 30%. This student begins his problem solving based on memory. They recall solving the same problem while studying. The following is a snippet of interviews with students who belong to the memory-based approach category.

Interviewer	:	After you read the first problem, what was the first thing that came to your mind?
Student	:	I thought it was a formula, but honestly, I forgot how to solve the problem!
Interviewer	:	What was asked there?
Student	:	Magnitude and direction of the net force on charge Q_A.
Interviewer	:	What steps did you take to solve the problem?
Student	:	Earlier I told you I forgot how to solve it, so because of this, Coulomb's law is the attractive force between charges. So because Q_A is related to Q_B and Q_C. Then look for Q_A & Q_B and Q_A & Q_C styles. Looking for the total force, so the magnitude of the Q_A & Q_B and Q_A & Q_C forces are added up.
Interviewer	:	What is the direction of the forces acting on the Q_A charge?
Student	:	Last time I did not draw the direction of your style, because I forgot.
Interviewer	:	If you get the answer, what do you do?
Student	:	What I do is look at the direction of the style, because minus means to Q_A. I'm confused about your style.

4.4. No clear approach

Two people or 20% of students are included in the no clear approach category. This group of students analyzes problems based on known variables and the work they do is not systematic and does not carry out evaluations. The following is an excerpt of interviews with students who fall into the no clear approach category.

Interviewer	:	After you read the first problem, what comes to your mind first?
Student	:	What I think about is how to do it.
Interviewer	:	What steps did you take to solve the problem?
Student	:	What is known, then done or answered.
Interviewer	:	After you finished counting and got the final answer, what did you do?
Student	:	After I got the final result, I just wrote it on the answer sheet.
Interviewer	:	Are you sure of your answer?

Student : Yes, sometimes I'm sure and sometimes I'm not sure, sir.

Mathematics is the main tool for expressing and applying physical laws [22]. Therefore, students need to master it well, especially as a prospective physics teacher who will help students learn later. Added here, although this study did not investigate intensively how students have difficulty using mathematics as a tool for problem-solving, but based on the analysis of written test data there are indications that students have weaknesses in applying mathematical procedures. The results of the quantitative analysis of student performance are shown in Figure 1 and Figure 2, where it can be seen that no one on the indicators using the mathematical procedure gets a score of five. This means that students' mathematical skills in using problem-solving physics cases are not sufficient.

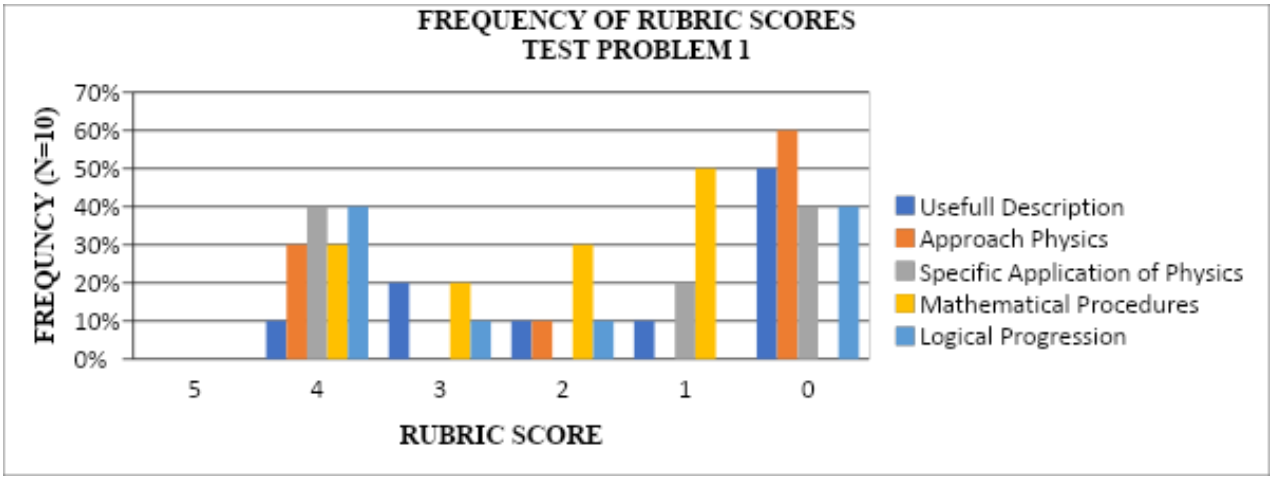

Figure 1. Rubric score frequency of test problem 1.

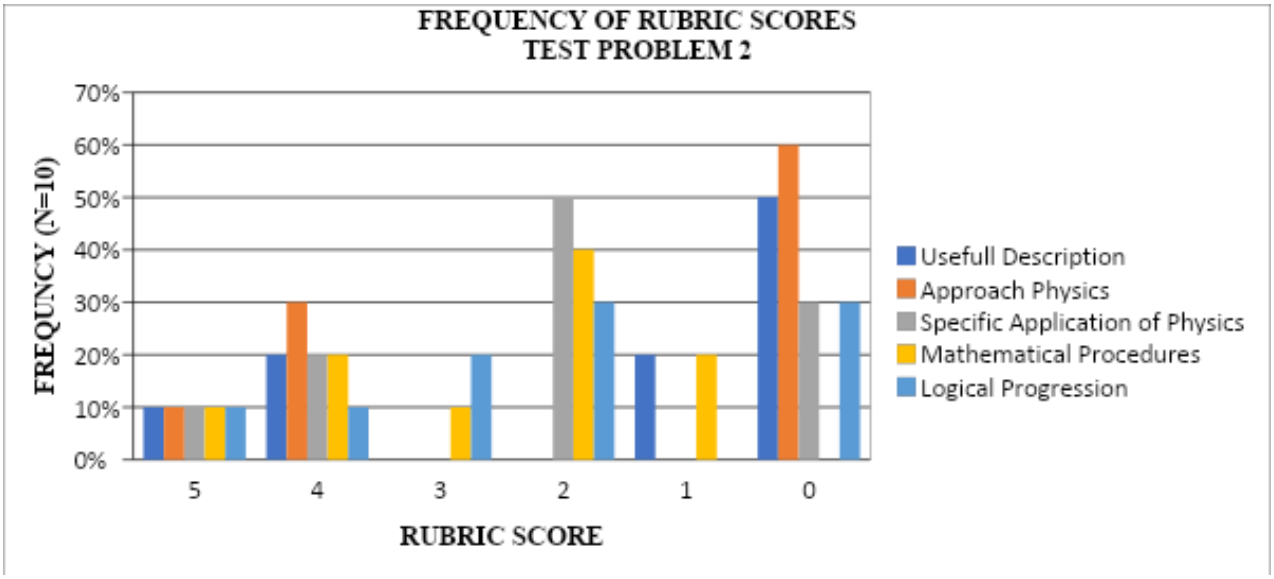

Figure 2. Rubric score frequency of test problem 2.

The findings of this study indicate that 50% of students in solving the problem the approach used is plug and chug. It was reported by Walsh that Turmarino and Redish in their study found that students used a plug and chug strategy in solving problems [5]. Participants in this study were students who had sat in their eighth semester ideally in solving problems using the scientific approach. Yet, in this study, no one was included in that category. The key characteristic of the scientific approach is that the solver solves problems with qualitative analysis that involves physics concepts, plans solutions, and does it in a systematic way that is guided by concepts, and at the end of the work carries out an evaluation [5]. These results are in line with research conducted by Zewdie, whose study investigates the approach used by students in solving problems with a total of 22 participants [6]. Riantoni et al., in their research, reported that only 2.27% of

students used a scientific approach from 44 research subjects [25].

5. CONCLUSION AND IMPLICATION FOR FURTHER RESEARCH

5.1. Conclusion

This study uses a case study design that investigates the approach used by students in solving problems so that it is difficult or even impossible to generalize to all students. Based on the results of the analysis and discussion, it can be concluded that there are three variations of the approach used by students in solving problems with the concept of electrostatic force, namely 50% plug and chug category, 30% memory-based approach, and 20% no clear approach.

5.2. Implication for Further Research

The findings of this research can be followed up by (1) developing an innovative learning program to build students' habits of scientific thinking and improving problem-solving skills and (2) conducting similar research with case study designs on other physics topics as a comparison, and enriching the findings.

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