The students' approach patterns in thermodynamic problem-solving at SMA lab school UNTAD Palu

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Abstract. The process of problem-solving carried out by students in solving physics exercises consists of different approaches. It is reviewed based on the diversity of students' ability levels in solving problems in physics subject. This study aims to describe the approach patterns used by students in the process of solving physics problems on the thermodynamic material at Senior High School Lab school UNTAD Palu. This type of research is qualitative research with a qualitative descriptive approach. The subjects in this study were 20 students of Grade XI Science 3 at Senior High School Lab school UNTAD Palu. Respondents in this study consisted of up to 6 students. The respondents were selected using the calculation of standard deviation and the average score of the results of the respondent selection test. The instruments used in this study were respondent selection tests, problem-solving tests, and interview guides. From the results of the research for the test of students' physics, the problem-solving ability was in the poor category with an average value percentage of 37.3%. Meanwhile, the approach patterns used by the students in the physics problem-solving process was interesting as it tended to use two approaches, namely structured Plug and Chug, as well as unstructured Plug and Chug.

1. Introduction
Physics is a part of natural science which studies matter and its motion and behaviour in terms of space and time, along with related concepts such as energy and force. Physics is a branch of science that focuses on the matter, energy, and the relationship between the two [1]. Learning physics is closely associated with problems which tend to require a solution to solve the existing problems. To be able to solve problems related to physics material, an understanding of the concepts related to the material is needed [2]. Problems which exist in physics can be solved if someone can understand the basic concepts of physics [3]. If the level of conceptual understanding that the student has is low, the student tends to have difficulty achieving cognitive abilities at a higher level than before. Understanding of a concept in problem-solving will lead to creative thinking in students [4].

The process of students in solving physics problems involves many errors in its implementation. These errors can be in the form of translation errors, concept errors, strategy errors, and miscalculations [5]. Besides, students have difficulty identifying problems correctly and not using the correct concepts. So this causes most students to answer questions given by researchers carelessly and as long as they explain the concepts on the material related to this study and do not relate to the correct concept. Some students answer with answers that are not meaningful [6].
Solving the problem itself is a planned process that needs to be carried out in order to find a certain solution to a problem that may not be obtained immediately. The strategy of solving the problem consists of 5 stages, namely the stage of identifying problems, describing problems, planning solutions, implementing the planned solutions, and evaluating solutions [7]. In the process of solving physics problems, students have various problem-solving patterns to find solutions to problems. Students develop various patterns to solve problems related to physics concepts [8]. Besides having various patterns, the approaches used in the problem-solving process also vary.

A problem-solving approach is an approach used in studying science to change an actual situation into a state, as one desires, by paying attention to systematic solving procedures. There are at least four approaches used by students in the problem-solving process, namely (1) a scientific approach, (2) a Plug and Chug approach (structured and unstructured), (3) a memory-based approach, and (4) no clear approach [9]. Referring to the approaches mentioned above, students often utilize the plug and chug as well as the memory-based approach in solving physics problems [9]. The diversity of students in the pattern of approaches used in solving physics problems can be seen from the students' physics learning outcomes which vary from high, medium, and low. The problem-solving model based on the scientific approach is more supportive in training students' critical thinking character than the others [10].

Physics exercises contain more problems that demand a solving process to get a solution which suits the problem. Students' physics learning outcomes which are still classified as low are thought to occur due to the students' lack of physics problem-solving ability [11]. In the process of solving physics problems, there are different solving patterns between students. For this reason, we need to observe the pattern of approaches that students use in solving physics problems with various student ability levels, from high, medium, and low in this study. Due to the type of research, this study can be used as evaluation material for educators in the next learning strategy related to the physics problem-solving process. This research is also aimed to observe the whole approach pattern of problem-solving and the tendency of the approach used by students at Senior High School Lab school UNTAD Palu. The approach used by students in solving physics problems can provide an overview of the students' ways of solving the problem. Thermodynamics material is one of the physics materials which is difficult to understand, but it forms the basis for various fields of science. The difficulties of students in studying thermodynamic material include lack of conceptual understanding of the relationship between pressure, volume and temperature as well as its relationship with the concepts of work, energy and heat [12]. Besides, students also have difficulty determining the Work (W) through the concept of the area under the curve based on the P-V diagram. In integrating information on diagrams/ graphs can help in the problem-solving process [13].

The purpose of this study was to describe the pattern of student approaches in solving physics problems on thermodynamic material at Senior High School Lab school UNTAD Palu. The benefit of this research is expected that, in the future, this research can be used as a source of reference in the learning process which is related to the patterns used by students in solving problems associated with thermodynamic material.

2. Research Methodology
This type of research is qualitative research with a qualitative descriptive approach [14]. The approach used is intended to describe and describe existing phenomena [15]. The instrument in this study was a test consisting of multiple-choice tests and test essays, as well as interview guidelines. Before carrying out research activities, the three instruments were validated by validators who were experts in the field. This research was conducted at Senior High School Lab school UNTAD Palu. The subjects of this study were 20 students of Grade XI Science 3. The research subjects will be categorized according to their initial knowledge regarding thermodynamic material into high, medium, and low categories using the results of calculating the average value (mean) and standard deviation. After categorizing the research subjects, six respondents were selected to continue the research to the next stage. The six respondents were given problem-solving tests in the form of essay questions totalling four-question numbers. They
are required to finish the essays using the Thinking Aloud technique. The respondents were then interviewed using the interview guidelines prepared by the researcher.

3. Findings and Discussion

3.1. Research findings

3.1.1. Physics Problem-solving Skills.
The data on calculation results obtained from students' physics problem-solving skills are presented in Table 1.

| Respondents | Score |
|-------------|-------|
| RT-14       | 57,6  |
| RT-19       | 42,8  |
| RS-01       | 29,6  |
| RS-17       | 58,4  |
| RR-04       | 20,0  |
| RR-10       | 15,6  |
| **Total score** | **224,0** |
| **Average score obtained** | **37,3** |

As displayed on Table 1, it can be seen that based on the criteria of making decisions, the students' physics problems solving skills on the thermodynamic materials are categorized as "poor" with the average score of 37.3 [11].

3.1.2. Approaches in Physics Problem-solving Skills.
As of the data which elaborated students' approaches in physics problem-solving are presented in the following Table 2.

| Question Item Number | Scientific Approaches | Plug and Chug | Memory-Based Approach | Unclear Approach |
|----------------------|-----------------------|---------------|-----------------------|-----------------|
|                      |                       | Structured    | Non-structured        |                 |
| 1                    | -                     | RT-14; RS-17  |                       | -               |
| 2                    | RS-17                 | RT-14         |                       | -               |
| 3                    | -                     | RT-14; RS-01; RS-17 | -                   | -               |
| 4                    | -                     | RT-14; RS-01; RS-17 | RR-04 | RT-19 | RR-10 |
4. Discussion

According to Zevenbergen, it is necessary to have adequate understanding and knowledge in solving problems and to have various kinds of strategies that can be chosen when facing different problems [7]. The results of the problem-solving ability analysis based on Table 1 are: the respondent with the highest problem-solving ability is RS-17 with a score of 58.4. The average score for the six respondents was 37.33, and the problem-solving average score was categorized in the poor category [9].

In the process of solving physics problems, students have different thoughts and strategies to find solutions to these problems. It is the same when viewed from the stages in finding solutions to problems and the approaches used by students themselves. From these differences, there are special patterns that students use in solving different physics problems according to the stages and approaches the students are using. The following shows the data on the problem solving process and a description of the approach pattern in solving student physics problems.

Based on the research results listed in Table 2, the physics problem solving process carried out by RT-14 tends to use a structured Plug and Chug approach. The pattern of the RT-14 problem-solving approach can be shown in Figure 1 below.

Using this approach, the RT-14 begins the process by analyzing the problem based on the equations needed to guide the solution. The solution planning stage is carried out based on the variables involved in the problem and processes it by substituting the variables into the formula and performing calculations with reference to the concept of the problem. The final stage, namely evaluation, which is the stage of checking back and evaluating the solution, is a form of conclusion given by students to the solution of the problem. At this stage, it was strengthened by the results of the interview which stated that RT-14 conducted an evaluation once. Based on the results of the analysis of students' answers, RT-14's approach to solving physics problems can be described as in Figure 2 below. Based on Figure 1, RT-14 has not been able to describe the problem in the questions. This approach pattern is consistently used by RT-14 in solving all problems on a given test.

The results of the analysis of the approach conducted by RT-19 concluded that these respondents tended to use an unstructured Plug and Chug approach and a memory-based approach in the process of solving a given problem. The following is the RT-19 problem-solving approach pattern shown in Figure 2.

In the unstructured Plug and Chug approach, RT-19 begins its stages by analyzing existing problems based on the variables needed to guide the solution. The planning stage is carried out by selecting the equation that matches the problem. The equation is then processed by substituting variables and performing calculations to obtain a solution to the problem. Apart from using an unstructured Plug and Chug approach, the RT-19 also uses a memory-based approach to problem solving. Using this approach, RT-19 analyzed the problem relying on his memory based on previous examples he had encountered. RT-19 tried to dig back his memory of the questions he had encountered before. Furthermore, in the
planning stage, RT-19 wrote down the equation according to the problem in the question. Then RT-19 processed it by referring to the concept based on variables. In Figure 2, it shows that the stages in solving physics problems carried out by RT-19 on both approaches only use 3 Heller stages, namely the stage of recognizing the problem, planning the solution and the implementation stage of planning.

![Figure 2. RT-19's Approach Patterns in Solving Physics Problems](image)

There are 2 trends in the approach pattern used by RS-01 in solving physics problems, namely the structured and unstructured plug and chug approach. This pattern can be shown in Figure 3 below.

![Figure 3. RS-01's Approach Pattern in Solving Physics Problems](image)

The structured plug and chug approach is carried out by analyzing the problem based on the required equations. RS-01 planning is carried out based on the variables involved in the problem and processing it by substituting the variables into a predetermined equation. Furthermore, RS-01 performs calculations by referring to the concept of the problem. In the final stage, RS-01 evaluates or re-checks the entire process to get a conclusion from the problem being solved. Unlike the previous approach, the unstructured Plug and Chug approach was used RS-01 by analyzing the problem based on the required variables. Planning is done by choosing an equation that matches the problem then it is then processed by substituting variables and performing calculations to obtain a solution to the problem by referring to the concept. Based on Figure 3, for the unstructured plug and chug approach, in stages it does not carry out rechecking of the solutions that have been obtained. In the second stage of this approach, RS-01 does not go through the stage of describing the problem in question.

Based on the results of the analysis of students' answers, the approach used by RS-17 tends to use 2 approaches, namely the scientific approach and the structured Plug and Chug approach. This pattern can be shown in Figure 4.
In the use of a scientific approach, RS-17 does this by analyzing the initial stage based on the context of the problem. At this stage, the identification of concepts related to the problem is put forward so that later the concepts will be linked. For planning and the process of a scientific approach, RS-17 is carried out by identifying the variables to be used and processing them systematically. The final stage carried out by RS-17 is in the form of evaluation which is a re-checking stage.

Figure 4. RS-17’s Approach Pattern in Solving Physics Problems

As with the previous approach, this approach is also in the final stage of checking the entire process. This is reinforced in the interview activities of respondents who stated that RS-17 in the process of working on the questions given always evaluates answers. The RS-17 pattern in Figure 4 shows that the structured plug and chug approach used by RS-17 only uses 4 stages, in contrast to the scientific approach which uses all Heller stages.

The next respondent was RR-04, which based on the results of the analysis showed that the pattern of the physics problem solving approach it used tended to only use the unstructured Plug and Chug approach. This can be seen in Figure 5 below.

Figure 5. RR-04's Approach Pattern in Solving Physics Problems

Using this approach, RR-04 is at the stage of analyzing the problem review based on the required variables. Planning carried out by RR-04 by selecting the appropriate equation with the problem. From
the predetermined equations, it is then processed by substituting variables and performing calculations to obtain solutions to problems and referring to concepts. The approach used by RR-04 in its application does not even carry out the evaluation stage of the entire problem-solving process.

Based on Figure 5, the approach pattern used by RR-04 is not complete using the Heller stage. The stages used by RR-04 consisted of 2 types, namely type 1 using 4 stages while type 2 only used 3 stages. Next is RR-10, which in the process of solving the problem uses 2 approaches, namely the unstructured Plug and Chug approach and an unclear approach. This is shown in Figure 6 below.

![Figure 6. RR-10's Approach Pattern in Solving Physics Problems](image)

The unstructured Plug and Chug approach taken by RR-10 is to recognize the problem in the problem by analyzing and reviewing it based on the variables in the question. Then in the planning stage, RR-10 chose a formula that was in accordance with the existing problem. With this formula, the existing variables are processed by substituting them into the predetermined equation. This process is carried out by referring to the concept of the problem. By using this approach, RR-10 does not carry out the evaluation stage of the process. This was strengthened when interviewing respondents, RR-10 stated that they did not carry out the evaluation stage.

Apart from using an unstructured Plug and Chug approach, RR-10 also takes an unclear approach to solving problems. This approach is carried out by RR-10 with the first stage of analyzing the problem based on the variables stated in the questions. Then process these variables randomly with reference to the concept. Similar to the previous RR-10 approach, for this approach, the RR-10 did not evaluate the solution obtained. Figure 6 above shows that the stages used by RR-10 by using these 2 approaches are the same, namely by doing only 3 Heller stages.

The tendency of the problem-solving approach patterns used by all respondents in this study generally uses two approaches, namely structured Plug and Chug and unstructured Plug and Chug approaches. This tendency is due to students' habits in the problem-solving process, which only prioritize equations and variables in the problem without knowing how the concepts in the problem are related to one another. The ability of students to understand a material can also lead to differences in the pattern of approaches used in solving physics problems, especially in thermodynamic material. Besides, students are also accustomed to not evaluating the entire problem-solving process. Several reasons students did not evaluate or recheck, feeling sure of the answer, forgetting to check again, or not being used to checking the answer again [16].

5. Conclusion
The students' physics problem-solving ability based on the results of the analysis showed that the students' problem-solving achievement was in the poor category with an average score of 37.3%. In the process of solving physics problems, students tend to use the Plug and Chug approach pattern, both structured and unstructured. An approach that is rarely used by students is scientific. When compared to the structured and unstructured plug and chug approach, the scientific approach is the approach that
has the most systematic stages. With the lack of application of this approach in the process of solving physics problems, it can affect student learning outcomes, especially in solving physics problems with a high level of understanding and analysis. This study has a small scope, using only six respondents. Henceforth, this type of research can be carried out with different materials, places, and larger scope than before; therefore, it can be used as a comparison between respondents in different learning environments.

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