Pre-Class Tutorial (PCT): an instructional strategy to improve pre-service physics teachers’ understanding about P-V-T-S diagrams in thermodynamic course

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Abstract. The Pre-Class Tutorial has been used to successfully improve the deep conceptual understanding and skills to draw and interpret the P-V-T-S diagrams in Thermodynamic Courses. This study was motivated by the previous research findings that students encounter the lack of conceptual understanding to draw and interpret the P-V-T diagrams to describe thermal process and Cycles of Ideal Gas. The analysis of the academic responses at written test shows that some of the students’ conceptual difficulties as follows. First, the biggest difficulty in each P-V, P-T, V-T and T-S diagram is to draw an adiabatic process. Second, the percentage of students who answer the P-V diagram correctly is higher than those who answer the P-T, V-T and T-S diagram. Third, Students prefer understanding thermal processes with their unique characteristic, such as isobaric with constant pressure, isotherm with constant temperature, and isochoric with volume constant. Finally, the lack of understanding the concept of P-V-T-S diagram also affects students’ understanding of various thermal cycles. Based on these findings, we developed the pre-class tutorial that facilitates students either to construct their own concepts to draw and interpret the P-V-T-S diagram. The descriptive method was used to involve 88 third-years students of Physics Education Department. The increased conceptual understanding was identified from the average of students’ achievement score on the instrument test. The findings showed that the use of pre-class tutorial effectively improves students’ conceptual understanding of the draw and interpret the P-V-T-S diagrams to describe thermal process and Cycles.

1. Introduction
Conceptual understanding is one of the most important things in the subject of Physics throughout the world [1, 2, 3]. Physics is the science that is closely associated with the influence of variables or between physical quantities. Those can be represented through the verbal, computational, mathematical, graphs, or diagrams [1]. Conceptual understanding (represented through the verbal, computational, mathematical, graphs, or diagrams) is one of the most important aspects of the study of Physics [4]. For the example in learning thermodynamics, the magnitudes which learned in the thermodynamics includes coordinate macroscopic scale or Pressure (P), Temperature (T), Volume (V), Entropy (S), Energy (U), Enthalpy (H), the Helmholtz free energy (F) and Gibbs free energy (G) [5].

Thermodynamics is the study of the interaction of heat, outside business or both between the system and the environment or other systems. To describe the state of a thermodynamic system can be evaluated from eight macro coordinates totalling thermodynamics. The experimental results show, to describe the
state of the thermodynamic system it can be described with just three macro coordinates, for example, the pressure (P), volume (V) and temperature (T). This is very advantageous quantitative analysis because the state of the system can be expressed mathematically f (P, V, T) = 0.

The system became a review in the course of thermodynamics only/restricted closed system. In addition to these restrictions, the processes in thermodynamics are seen underway quasistatic so that every moment is always regarded the equilibrium state of the system. Consequently, the state of the system can be expressed mathematically in the equation of state. As an example of an ideal gas system can be expressed by PV = nRT. In addition to the equation of state, the state of the system can also be expressed in the form of diagrams P-V-T. The diagram is part of multi-representation capabilities. Representation is a form that can describe, represent or symbolize an object. Through the representation capable of representing, depict or symbolize an object or process of a phenomenon. How that is done by the students in a representation of the physical problems of an increasingly diverse show the maturity of thought and the good understanding of such a concept. Students are able to have the ability to represent the same concept with a different form and manner referred to by multiple representations [6, 7].

The data of preliminary study was obtained from the analysis of the students’ answers on the written test subjects thermodynamics shows one of the students’ difficulties is to create and interpret diagrams of PV, PT, VT, and TS on the process and the thermodynamic cycle of a condition of thermal equilibrium for the process and the thermodynamic cycle for a closed gas system that meets the ideal gas equation of state. The thermodynamic process in question is the isobaric process, isotherm, isochoric and adiabatic, while the thermodynamic cycle includes the Cycle of Carnot, Diesel, and Otto. In general, difficulties finding students as follows. First, the biggest difficulty is in describing PV, PT, VT, and TS is the adiabatic process. Second, the rate of students’ correct answers at the higher than the diagrams of PV for PT, VT, and TS. Third, the students whose better understand the characteristics of the typical thermodynamic process, such as isobaric process with constant pressure, isotherm with constant temperature, and isochoric with constant volume. The poor understanding of students on the depiction and interpretation in the PV, PT, VT, and TS diagrams to process turns their impact on the lack of understanding in describing the thermodynamic cycle in the PV, PT, VT, and TS diagrams. In fact, this understanding is important to describe the process or the thermodynamic cycle, due mainly to the PV and TS diagrams for processes and cycles have physical meaning as the work done by/on the system. As an example, the pressure-volume (P-V) and temperature-entropy (T-S) the diagrams are often used as teaching aids to describe refrigeration processes [8, 9].

In the previous research, the pre-service physics teachers’ difficulties in understanding the P-V-T-S graphics for ideal gases is by using virtual computers. The results showed that pre-service physics teachers are able to create graphs P-V-T-S and there is an increasing understanding of creating the graphics. But the results are still not optimal. The advanced analysis using a virtual show, students only focus on the trend curve shape. For most students less understand exactly how to find the inscribed form of the curve. This is palpable in the answers of students who answered some of her curves to confuse graphs PV, PT, VT, and TS.

This study will emphasis on the usage of Pre-Class Tutorial (PCT) to improving students’ understanding of the PV, PT, VT, and TS diagrams in the ideal gas. The application of pre-class considered tutorial in learning is effective in improving students' conceptual understanding [10]. Technically, PCT provided earlier in the hope students be able to fill it first. It persisted that they try to understand the material to be studied and better prepared when learning in the classroom. Readiness to learn is very important in determining the optimal learning outcomes. This learning emphasis on active learning, cooperative and utilize diverse representations to solve problems. Heller also, devise a strategy for problem solving through collaborative learning. Eric Mazur designing a learning Peer Instruction (PI) to teach Physics at Harvard University [10]. All of the instructional design is seen be able to be accomplished with the enactment of the PCT.
2. Method
The method that utilized is quasi-experimental with its initial analysis of the descriptive to the development of Pre-Class Tutorial (PCT). The subjects who involved in this study are 88 students of Physics Department of the academic year 2016/2017. The test instrument used in the form of a written test in the form of an essay. This is so that students can answer the questions openly, to encompass all possible as students’ answers. Analysis of the prospective students’ understanding and interpretation of Physicists in making PV, PT, VT, and TS diagrams from the thermal equilibrium conditions for the process and the thermodynamic cycle is obtained from the students’ written test answers.

3. Discussion
The data that attained from the students’ answer sheets. Based on the data from the students’ answers on the answer written tests, it be able to be gritty the percentage of students' understanding level in making and interpreting the PV, PT, VT, and TS diagrams from the thermal equilibrium conditions for the process and the thermodynamic cycle, In general, the data presented in Table 1.

| Diagrams | Academic Year | Percentage of Students with the right answer (%) |
|----------|---------------|--------------------------------------------------|
|          |               | Thermodynamic Process |              | Thermodynamic Cycle |
|          |               | Isobaric | Isotherm | Isochoric | Adiabatic | Carnot | Diesel | Otto |
| P-V      | 2015/2016 (N=78) | 74.1     | 79.5     | 77.1     | 76.5     | 81.2   | 79.4   | 73.5  |
|          | 2016/2017 (N=88) | 90.3     | 88.5     | 85.1     | 80.0     | 3.7    | 84.6   | 86.8  |
| P-T      | 2015/2016 (N=78) | 74.1     | 74.1     | 75.3     | 73.5     | 82.4   | 76.5   | 73.5  |
|          | 2016/2017 (N=88) | 83.1     | 79.7     | 79.0     | 76.9     | 86.6   | 80.8   | 79.0  |
| V-T      | 2015/2016 (N=78) | 72.4     | 74.1     | 74.1     | 70.5     | 72.4   | 72.5   | 75.5  |
|          | 2016/2017 (N=88) | 77.0     | 78.8     | 76.6     | 77.3     | 84.7   | 81.7   | 78.2  |
| T-S      | 2015/2016 (N=78) | 67.6     | 70.1     | 76.5     | 69.2     | 74.1   | 68.4   | 68.5  |
|          | 2016/2017 (N=88) | 74.4     | 75.6     | 75.6     | 72.3     | 82.4   | 81.3   | 75.9  |

Based on Table 1, it looks that the correct answer to the achievement of the students in the academic year 2015/2016 still needs to be improved. This achievement, still relatively increased compared with the previous academic year. In the academic year 2015/2016, learning using virtual media. Review of these data, the lowest achievement found in understanding the process of adiabatic. This is apparently due to the characteristics of the adiabatic process typically “no interaction of heat, or Q=0”, no amount of which be able to be represented directly in the PV diagram, PT, and VT. Second, the rate of students’ correct answers at the higher PV diagrams and the lowest is the TS diagrams. The students accustomed to in the PV diagram for the presentation of equilibrium thermodynamics to the various regular process they discovered in the PV diagram. Third, the students with better understand the characteristics of the typical thermodynamic process, such as isobaric process with constant pressure, isotherm with constant temperature, and isochoric with constant volume. That is to diagram the magnitudes involved, the students can make for staying draw a straight line that indicates that the value is constant. Fourth, the students with lack of understanding in the diagrams of PV, PT, VT, and TS to illustrate the impact on the low thermodynamic process of understanding their depictions PV, PT, VT, and TS diagrams for the thermodynamic cycle. The test instrument being tested to the students, as presented in figure 1. As the example of student’s answer is shown in figure 2.
In thermodynamics, we discuss many thermal processes, i.e. the change of macroscopic coordinates of a system due to interacting with the environment, include a isochoric, isobaric, adiabatic and isotherm. Explain those processes qualitatively for ideal gases. Represent each process by using $P-V$, $P-T$, and $V-T$ diagram, and provide an interpretation (mathematically or physically) based on the diagrams you make.

**Figure 1.** A written problem posed on the examinations.

**Figure 2.** The sample of student’s answer.

From the student’s answers, it appears that for the diagrams of PT, VT isotherm and the adiabatic process is made in the same curve as if they are the same characteristics. The analysis continuation of the interview the student obtained several findings as follows. First, The adiabatic process similar to the process isotherm. For PV diagram only different steepness. Isotherm process steeper than the adiabatic. Theoretically, adiabatic similar to the isotherm, but PV diagram on adiabatic should be steeper than isotherm. This is due to adiabatic process factor (constant Laplace,) or while isotherm. Second, In the adiabatic process no heat interaction, $Q = 0$, based on the equation, means there are also changes in temperature so that the adiabatic process "no change in temperature" means the temperature constant. Ideally, both of the conceptions associated adiabatic $Q = 0$, and based on the equation, means there is no temperature change also applies only to systems that only interact heat only (release or absorption). However, for the gas in thermodynamic system reviews the interaction not only the heat, but there is the interaction of heat ($Q$), business ($W$) or both. In addition, in thermodynamics is not generally accepted that each receive/make effort then will be converted into heat, which is release/absorption, but can also to be converted in the form of changes in the energy ($U$).

PCT is one of the learning strategies to facilitate learning process to improve understanding students in PV, PT, VT, and TS diagrams. A learning process is one of the important aspects of the improvement of students' conceptual achievement. In Addition, PCT accommodates students' abilities including student difficulties. The students' learning capability will determine the role of a teacher conducting the learning in a class. The implementation of PCT deemed able to improve students’ understanding. Because of the related representation, virtual presence is very important to strengthen or clarify their
understanding related P-V diagram, P-T, V-T, and T-S for the process and the thermodynamic cycle. As an example for the isobaric process, PCT designed as shown in figure 3.

The tutorial method allows students to check for themselves the inconsistent understanding of the concept and an error of reasoning in their answers. However, its use in the population of students who are not familiar with the qualitative conceptual questions requires a more intensive effort. However, the tutorial has been proven effective in improving the ability of students complete qualitative and quantitative questions. The tutorial has also been widely adopted in a variety of lectures and laboratory activities, such as mathematics, quantum mechanics, and lab Physics. The overall results are exactly the rational development of pre-class tutorial in one LPTK in Bandung. The tutorial developed by McDermott at UW is a supplement that is used after learning to replacing recitation session (reinforcement concepts or response in the terms used in UPI). While with the effectiveness of this tutorial on the use of pre-lab activities, the impact of assignment in the form of conceptual questions that support improved learning outcomes and to overcome the weaknesses of students in reading before the lecture, then on the rational basis of the pre-class tutorial designed. Tutorial pre-assigned classes to students before the lecture takes place [9].

Commonly, the implementation of the PCT increases the pre-service physics teachers’ understanding of the prospective teachers in understanding the physics of the curve P-V diagram, P-T, V-T, and T-S. This can be seen from the increase in the percentage of students' answers are presented in Table 1. The students’ answer percentage in academic 2016/2017 academic year higher than 2015/2015. In tallying to the use of the PCT, it also makes the process of the learning process in the class become more active because the students are better furnished in following the discussion. This requires learning activities able to make the students’activeness in order to build up the students' knowledge through a series of activities that encourage students toward discovery process [11].

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**Figure 3.** The example of PCT for the thermodynamic process.
4. Conclusion
The development of PCT has been done on a thermodynamic study sub-material of PV, PT, VT, and TS diagrams for the thermodynamic process and the cycles. The development is based on the students’ conceptual difficulties. The results of students’ learning achievement in the PV, PT, VT, and TS diagrams is higher than before the implementation PCT. These finding alternative solutions give the improvement of students' understanding of the PV, PT, VT, and TS diagrams for the process and the thermodynamic cycles.

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