CHAPTER 8

Conclusions and discussion

In the previous chapters, I have presented the experimental setups and results of: thermodynamics conceptual survey, Seebeck effect demonstration, thermodynamics of rubber band, fog in the bottle demonstration, pee-pee boy demonstration, movable syringe demonstration, and physics education for evaluation of thermodynamics concept. Here, I will conclude them again to be guided for other possible studies.

8.1 Thermodynamics conceptual survey

As mentioned in the previous section, three models for an ideal gas law were identified to be analyzed with model analysis and the results are shown in Table 7.1. The eigenvalues for the class states corresponding to the null models were very small. This indicates that most students use either Model 1 (a correct model) or Model 2 (an incorrect model). In addition, the primary class model states have eigenvalues around 0.6. Then, the class model states on this concept were displayed on a model plot, as shown in Figure 7.1. The class model states or eigenvectors with dominant eigenvalues can be represented as a class model point on the model plot with a coordinate (P_1, P_2). From Table 7.3, vertical and horizontal components for pre/post class model point are calculated. From the model plot in Figure 7.1, both pre and post model points were located in the Model 2 region. This indicates that most students in the class still had a misconception in the ideal gas law even after an instruction. Due to the model analysis, the characteristics of this misconception are known, so an instructor can use this information to improve teaching of this class. In this work, it seem that model analysis is a method to analyze student's knowledge states in a large class with multiple-choice questions. Model analysis can determine probabilities of students using alternative models. This information about student alternative conceptions in the ideal gas law will be used to improve an instruction.

8.2 Seebeck effect demonstration

In this study, it found that the students were exited with the experiment. They had seen the temperature changing and the voltage generated from the thermocouple and thermoelectric module. The Seebeck effect was display in the real visuality, so they can calculated the Seebeck coefficient for the thermocouple. The IR-camera was used to display the temperature gradient of thermoelectric module while the voltage also collect by digital voltmeter at the same time. The data was valuable to understanding the concept of Seebeck effect. Finally, this demonstration help the student to understanding the Seebeck effect and they very satisfied to see this demonstration by the result from satisfaction questionnaire.

8.3 Thermodynamics of rubber band

In this study, it presented that the students were interested in using the rubber band in the physics experiment for thermodynamics, because it is a new system and a different from what is usually used in learning, such as ideal gas or Vander Waal gas (which are more difficult to understand than the rubber band activity). In the first part of the experiment, they were confused about the change of each parameter that was affect by the change of the internal energy of the system. Then, they were forced to deal with multiple variables and interpret the integration output into physics' context. In the second experiment, they worked with changes in water temperature. It was hard work to keep the temperature constant. In addition, they were confused in to analyzing and interpreting, and then graphing the data from equations. Finally, the result from TDT was shown that the post-test score was higher than pre-test. The correct responses confirmed that the active learning approach can improve the students' understanding in thermodynamics.

8.4 Fog in the bottle demonstration

From the experiment, it presented that the pressure and temperature of gas in the bottle were decrease but the volume was increase. An abrupt adiabatic expansion of gas at high pressure indicated to a temperature decreasing with condensation of water vapour which caused fog formation. The work in reversible adiabatic process is more than irreversible adiabatic process within the same initial state. This experiment is example

of adiabatic process that occurred in daily life. This results is quite general since the irreversible process of the Carathéodory principle.

8.5 Pee-pee boy demonstration

From this study, it presented a way to implement pee-pee boys as an interactive lecture demonstration. Using the pee-pee boys ILD gives an opportunity for students to explicitly present their reasoning. The data analysis indicated that students often used several dominate misconceptions as their reasoning such as pressure depends on temperature and heat causes temperature to rise. When these misconceptions are identified, an instructor needs to discuss with students making them realize the limitations of their misconceptions. From the questionnaire, students found the pee-pee boys ILD to be interesting and exhibiting the first law of thermodynamic quite well. This ILD can be also employed at either college or high school physics in order to present an exotic example of the first law of thermodynamics.

8.6 Movable syringe demonstration

In this study, it can provide students with a valuable experience. It only pointed out student difficulties dealing with multi-variable in an ideal gas law. If students overcome these difficulties, they will be able to develop correct understanding of thermal process and the first law of thermodynamics. The error of this experiment is the friction between the piston and the barrel of the syringe. Because of this friction, it is hard for the piston to slide up. . Opportunely, it is easy to solve this problem by cleaned the syringes. It can be cleaned using a detergent or acetone and water. This experiment is appropriate for the introductory physics course in university level and also in high school level. Glass syringe has a minor problem of maintaining, easy to set up, and inexpensive so it is a comfortable adding to the tools of any physics department.

8.7 Physics education for evaluation thermodynamics concept

In this study, it seem to successfully develop the Thermodynamic Conceptual Test or TDT, which is a two-tier multiple-choice test with 15 questions. Test reliability was established using multiple methods. The TDT was then implemented to diagnose alternative concepts of the first year students taking a fundamental physics course at Chiang Mai University in 2012 and 2013. Follow-up interviews with seven students were conducted to provide more details about the alternative concepts. Nine alternative

concepts were identified from students' responses to the second-tier of the test. The predominant alternative concepts are AC1 (Temperature is the amount of heat contained in a body), AC6 (Temperature increase causes the pressure to increase), AC7 (According to the second law the entropy of the system must increase) and AC9 (In the real process, the entropy of the system plus that of the environment remains the same). To help students become more aware of AC1, physics instructors should emphasize the concepts of extensive quantities (heat transfer) and intensive quantities (temperature). Moreover, the results also support the observation that students seem to use functional-reduction reasoning when encountering multi-variable situations, in this case the specific heat equation and the ideal gas law AC1 and AC6. The instruction regarding these two equations has to be carefully planned to make students aware of their functional-reduction reasoning. The TDT provides physics instructors with a valuable resource for evaluating student understandings both at the beginning of a thermodynamic course and at the end, and the questions in the test can be used to generate in-class discussion on teaching and learning thermodynamics. Two-tier multiple choice questions were not only used to determine the level of the students' conception but also the main causes on students' thinking. With the two-tier test, students become more aware of their own knowledge can also be determined. Moreover, two-tiered multiple choice questions can also built relationships between the cause and the result of the knowledge. Similarly, two-tiered multiple choice questions for the different units could also be prepared and applied for determining students' conceptual structure in different concepts.