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THE LEVEL UNDERSTANDING OF THERMODYNAMIC CONCEPT FOR PHYSICS AND CHEMISTRY UNDERGRADUATE STUDENTS

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Abstract. Thermodynamics is an abstract concept making it difficult for physics and chemistry undergraduate student to understand it. The purpose of this research is to know the level understanding of the fundamental concepts of thermodynamics so that lecturers can develop strategies to teach thermodynamics appropriately. An exploratory small-scale study was conducted on students majoring in physics and chemistry to evaluate an understanding of heat, temperature, energy, work, thermodynamic processes and the first law of thermodynamics. The research sample consisted of 20 undergraduate students who were randomly selected from two majors, namely physics and chemistry. Data were collected through a diagnostic test to determine the level understanding of students' concepts which consisted of 20 questions. In addition, interviews were conducted with those of 20 students related to given questions. The results showed that the level of students' conceptual understanding of the concept of thermodynamics was still low. The main reasons that cause students have problems in understanding thermodynamic concepts are the concept of thermodynamics is an abstract physics concept and the matters of thermodynamics are lack in explanation and interpretation of phenomena and not linking them to daily life.

Keywords: *The Level Understanding, Thermodynamic, Physics and Chemistry*

INTRODUCTION

Thermodynamics is one of the most popular subjects even though known as the most difficult subject for student (Anderson, Taraban, & Sharma, 2005; Junglas, 2006; Mulop, Yusof, & Tasir, 2012; Sokrat, Tamani, Moutaabbid, & Radid, 2014). The basic concepts such as heat, temperature, energy, work dan thermodynamic process and the first thermodynamic law that cause thermodynamics is an important subject and challenging for student (Jasien & Oberem, 2002; Krummel, Sunal, D., & Sunal, C., 2007; Sozbilir, 2001; Yeo & Zadnik, 2001). The main challenging for student is the high abstraction of concept in thermodynamics (Carson & Watson, 2002; Chiu, 2007; Cox, Belloni, Dancy, & Christian, 2003; Junglas, 2006). Also, this is because the concepts are related to daily experience that cause they are in wrong perceptions in understanding concepts. The previous research attributed to understanding concepts of thermodynamics revealed that under graduate student have many problems in learning thermodynamics. One of problem was the students could not differentiate the concept of heat and temperature (McDermott, 2003). They considered that heat and temperature was the same meaning dan they used reciprocally (Niaz, 2006).

Based on empiric study, the misconception was caused by opinion that heat was matter as air or vapor and heat was the opposite of temperature and temperature of object depend on volume and the size of the object. Most student believe that metal could transmit, absorb, hold cold better than other object thus metal was the best choice to hold object remain cold. Most student have opinion that temperature could be measure that make it different with heat and most student stated that temperature measure the heat while other students stated that temperature could be measured while heat could not be measured.

The previous research showed that the conceptualization of student was different with scientific ideas that will be studied in thermodynamics and it give the

real influence to student's understanding about related scientific idea. In this context, knowing the level of conceptual understanding in terms of thermodynamics is really important. The understanding of concept can be defined in various. In general, it is defined as learning with understanding will be contrast to the learning with declarative knowledge meaning that students are not only remember related to phenomena or process (Darmofal, Soderholm, & Brodeur, 2002). The understanding conceptual need more that remembering those relations, it needs the ability to apply previous learning in some type of unexpected experiences.

Learning thermodynamics for most students are difficult. This is because thermodynamics is represented by many equations of mathematics which can be learned if students understand the fundamental concept of thermodynamics. This research is attributed to know the level of understanding for physics and chemistry under graduate student and explore reasons the difficulties faced students related to the construction of knowledge. The construction of knowledge is developed by an interaction process among the existed conception that have been belonged by student with outside stimulus, thus when students sit in the class room to study any course, they will construct their existed conceptual framework in their mind and connect to new stimulus that they get in the new learning process. This fact can cause the modified of existing concept or created new concept. There are many methods in which the learning process can cause un expected result.

There are many research that explore the understanding of student related to science with different topics in the various level of education system that show many mismatch between the accepted concept and student's concept (Pfundt & Duit, 1994; Carmichael, Driver, Holding, Phillips, Twigger, & Watts, 1990). The source of student's conception depend how they build knowledge. When students construct their own understanding, they will be influenced by their own perspective that often be wrong (Osborne & Wittrock, 1985). Knowledge is developed by using interaction process between the existed concept of student and outside stimulus. It means before students sit in class room for listening a course, they build their own frame. After getting explanation from lecturer, student may be modified the existed concept or build new concept.

The unappropriated between prior student knowledge and expectation of lecturer is one reason why the learning result is not in expectation. If students do not have the beginning knowledge that is needed then building a new concept becomes difficult. In fact, if student have developed incorrect understanding and saved them in their mind making new learning is really difficult. The knowledge is arranged into three categories namely Matter, Process and Mental State (Chi, Slotta, & De Leeuw, 1994). If the concepts are wrong, this makes difficulty in changing of conceptual to give scientific understanding. Another difficulty comes from cognitive aspects related to the interaction process between the existed knowledge and new input. In general, thermodynamics concepts are abstract which was stated by Dixon and Emery (1965) who categorized concept depend on the level of student abstraction that can give impact on learning strategies.

METHOD

The data are collected from the sample that are chosen randomly to get 20 physics and chemistry undergraduate student at Medan State University. The student answer 20 problem the results will be analyzed. After answering 20 problems, the student will be interviewed. The purpose of interview is to know the difficulty of student in understanding fundamental concept of thermodynamic. The result will become guide in terms of finding the proper teaching strategies.

RESULT AND DISCUSSION

The percentage of correct answer for both physics and chemistry undergraduate student is represented in the following table.

Table 1. The percentage of correct answer for both physics and chemistry undergraduate student in answering question

Question Number	Concept	Percentage of correct answer for Physics student	Percentage of correct answer for Chemistry student
1	Heat	100	87.5
2	Work	75	25
3	Work in closed system	25	25
4	Thermal equilibrium	37.5	25
5	Heat exchange	0	37.5
6	The type of system	12.5	0
7	Heat Transfer	75	62.5
8	Adiabatic process	87.5	75
9	Specific heat capacity of water	12.5	12.5
10	Adiabatic thermodynamic process	87.5	87.5
11	Thermodynamic variable	50	37.5
12	The state function of system	75	87.5
13	Ideal Gas	75	50
14	Isothermal thermodynamic process	12.5	50
15	The mechanical work	25	12.5
16	The first law of thermodynamics	37.5	37.5
17	The relation T and V	50	62.5
18	Ideal Gas	62.5	62.5

19	The dependence of internal energy	25	37.5
20	Thermal conductivity	87.5	62.5

From the result shown in table 1, the lowest percentage of score for physics undergraduate student is 0 attributed for the question 5. This question is "what happen if there is heat exchange between pure water (liquid) and surroundings at constant pressure" and the result show that most physics undergraduate student answer that temperature does not change but physical state of water change. This answer interprets that student does not understand about the concept when the heat evolved (either released or absorbed) at constant pressure is equal to the change of enthalpy that can change the internal energy. Due to the change of internal energy, this causes the change of temperature. While for chemistry undergraduate students have difficulty in answering question number 6 with the question is "The system which is represented by $\Delta U = 0$ indicates ….". The result shows that most student answer closed system. It means that students do not understand about the differentiation between closed system and adiabatic system. Students do not know that adiabatic system is defined as a system in which no heat transfer takes place. This does not mean that the temperature is constant, but rather that no heat is transferred into or out from the system. While closed system is defined as a system in which only the exchange of energy is allowed but the exchange of matter is not allowed. In terms of the highest percentage of correct answer for physics under graduate students attributed to the question 1 which is reveal that heat is an energy transformed to other forms. On the other hand, for chemistry under graduate student, the highest percentage of correct answer is 87.5 which attribute to the question 1; 10 and 12.

Next, it is important to note the wrong answer of student both physics and chemistry in the following table

Table 2. The description of some of wrong answer about thermodynamic concept

Question Number	Concept	Wrong answer statement of physics undergraduate student	Wrong answer statement of chemistry undergraduate student	Correct Answer
1	Heat	-	Heat is not a type of energy, but a something that flows from hot objects to cold objects	Heat is an energy that can be transformed to other forms
2	Work	Work is an energy not transformed to other forms	Work is not a form of energy	Work is an energy that can be transformed to other forms
3	Work in closed system	In the closed cylinder contained ideal gas with a moving piston generate work which depend on time	Work for ideal gas depends on type of matter	In the closed cylinder contained ideal gas with a moving piston generate work which depends on thermodynamic process of system
4	Thermal equilibrium	The difference in temperature between two connected systems cause exchange of matter	The two connected system with different temperature leads to exchange of substance	The two connected system with different temperature leads to heat exchange
5	Heat exchange	Heat exchange between pure water (liquid) and surroundings at constant pressure cause the change of physical state of water without the change of temperature.	At constant pressure, the exchange of heat between pure water and surrounding leads to temperature stability with changing of physical state of water.	At constant pressure, the exchange of heat between pure water and surrounding leads to temperature change with stability of physical state of water
6	The type of system	A system with $\Delta U = 0$ represents closed system	The system which is represented by $\Delta U = 0$ indicates closed system.	A closed system is that in which only the exchange of energy is allowed but the exchange of matter is not allowed. While isolated system both

				energy and matter do not exchange.
7	Heat Transfer	The two system which are mutually connected have temperature T_1 and T_2 respectively with specific heat capacity C_1 and C_2 respectively. Thermal equilibrium cause the final temperature T which depends on specific heat capacity C_1 and C_2 only.	The two connected systems with temperature are represented with T_1 and T_2 respectively, while specific heat capacity are represented with C_1 and C_2 respectively. The final temperature namely T at the thermal equilibrium is connected to temperature T_1 and T_2 only	The temperature of two contacted object T_1 and T_2 and their specific heat capacity C_1 and C_2, respectively. The final temperature T at the thermal equilibrium can be derived using Black principle which depends on temperature T_1, T_2 and specific heat capacity C_1, C_2.
8	Adiabatic process	The absorbed heat of system is zero identifying transformations at constant temperature (isothermal)	The system which does not absorbs heat represent isothermal process	An adiabatic process is defined as a process in which no heat transfer takes place. This does not mean that the temperature is constant, but rather that no heat is transferred into or out from the system meaning that $\Delta Q = 0$
9	Specific heat capacity of water	Specific heat capacity of water depends on volume water.	Specific heat capacity of water depend on volume water	Specific heat is defined by the amount of heat needed to raise the temperature of 1 gram of a substance 1 degree Celsius (°C). Water has a high specific heat, meaning it takes more energy to increase the temperature of water compared to other substances. the transferred heat depends on three factors: (1) The change in temperature, (2) the mass of the system, and (3) the substance and phase of the substance
10	Adiabatic thermodynamic process	Adiabatic process of thermodynamic is characterized by $\Delta U = 0$	Adiabatic process of thermodynamic is characterized by $\Delta H = 0$	An adiabatic process is defined as a process in which no heat transfer takes place meaning that Q = 0.
11	Thermodynamic variable	In the adiabatic thermodynamic process, T is constant while P and V are variable.	In the adiabatic thermodynamic process, V is constant.	In the adiabatic thermodynamic process, T, P and V are variables.

12	The state function of system	The state of function is related to initial state only.	The state of function is related to final state only.	The variation of state function is related to the initial and final states.
13	Ideal Gas	Ideal gas can not be found in the nature. This is an imaginary gas.	Ideal gas can be provided in the normal condition	Many gases such as nitrogen, oxygen, hydrogen, noble gases, some heavier gases like carbon dioxide and mixtures such as air, can be treated as ideal gases within reasonable tolerances over a considerable parameter range around standard temperature and pressure. The gases just show ideal behavior under certain conditions of temperature and pressure. For gas to be "ideal" there are four governing assumptions: The gas particles have negligible volume. The gas particles are equally sized and do not have intermolecular forces (attraction or repulsion) with other gas particles. The gas particles have perfect elastic collisions with no energy loss.
14	Isothermal thermodynamic process	The system consists of ideal gas found inside a closed cylinder with a moving piston. The gas has an isothermal reversible expansion. The quantity of internal energy increase.	The system consists of ideal gas found inside a closed cylinder with a moving piston. The gas has an isothermal reversible expansion. The quantity of internal energy decrease.	characteristic of isothermal reversible expansion is the increasing volume meaning that the pressure decrease. Another characteristic of isothermal process is $\Delta U = 0$ meaning that the internal energy is stable.
15	The mechanical work	The work of system which experience an isothermal reversible expansion is always negative	There is no work done from the system or on the system for system experiencing an isothermal reversible expansion	The system experiencing an isothermal reversible expansion leads to positive work. This because during this process (shift from initial state to final state), the volume increase.
16	The first law of thermodynamics	There is no heat for the system for system	The heat of system which experience an	From the first principle of

		experiencing an isothermal reversible expansion	isothermal reversible expansion is always negative.	thermodynamics, the system experiences an isothermal reversible give positive heat which. It can be derived using the formula $dQ = dU + pdV$ with $dU = 0$ for isothermal process and due to the increasing volume give $pdV > 0$.
17	The relation T and V	If the temperature of ideal gas is double, the pressure does not change.	There is no relation between T and V in terms of ideal gas	The quantity of T,V and P for ideal gas can be defined using the expression $PV = nRT$ meaning that if temperature is double, this influence the value of PV.
18	Ideal Gas	A sample of ideal gas has an internal energy U and is then compressed to one-half of its original volume while the temperature stays the same. The new internal energy will be $\frac{1}{2}U$.	A sample of ideal gas has an internal energy U and is then compressed to one-half of its original volume while the temperature stays the same. The new internal energy will be $\frac{1}{2}U$.	The internal energy of ideal depend on temperature. It means that if the temperature stay the same, the internal energy does not change.
19	The dependence of internal energy	The internal energy of system consisted of ideal gas depend on volume.	The internal energy of system consisted of ideal gas depend on pressure.	The internal energy of system consisted of ideal gas depend on temperature.
20	Thermal conductivity	A piece of metal and a piece of wood that are placed in the same room, the piece of metal feels much colder than the piece of wood. This happens because of the difference in density.	A piece of metal and a piece of wood that are placed in the same room, the piece of metal feels much colder than the piece of wood. This happens because of the difference in temperature.	A piece of metal and a piece of wood that are placed in the same room, the piece of metal feels much colder than the piece of wood. This happens because of the difference in thermal conductivity.

The science undergraduate students have difficulty in understanding the concept of heat, work specific heat capacity, internal energy, state function, ideal gas, thermodynamic process, type of system and others. Student also get difficulty in understanding concept of the first law of thermodynamic in explaining relationship work, heat and internal energy. In terms of ideal gas, student get difficulty in understanding properties and condition of ideal gas. The difficulty also is found in interpreting thermodynamics phenomena such as the characteristic of isothermal process in terms of constancy of internal energy and heat exchange. Student consider that there is no heat transferred during isothermal process and also believe that there is a change of temperature during the change of phase of matter such as melting ice. This belief is caused by the daily phenomenon when ice melting needs heat making them believing that temperature is raising. In fact, this heat called latent heat is used to change phase of solid ice into liquid water. In terms of specific heat capacity, student think that metal and iron need the same of time duration in heating the to temperature T. This is because their wrong observation. Student also belief that the specific heat capacity of matter is independent of temperature meaning that the heat to raise temperature from 271 K to 272 K is the same as the heat to raise temperature from 300 K to 301 K. In fact, the heat will be different even though for both case the difference is 1 K. With regard to the concept of type of system, student confuse to differentiate between open, closed and isolated

systems. Student also confuse thermodynamic process related to isothermal, isobaric, isochoric and adiabatic processes. The next problem is related to the concept of work, student do not realize that work is a form of energy and its value at constant pressure is different from that at constant temperature. In terms of perfect gas, student consider that it is an imaginary gas which is not found in nature, while it can be found since it is a real gas in specific conditions with high temperatures and low pressures.

To find the reasons of the difficulties faced the student, it is important to know the answer of the question "What are the difficulties faced students in learning the concepts of thermodynamics" And from the analyses, these the answer: (1) Thermodynamics is an abstract and complex concepts terms that are difficult to understand (work, heat, temperature, specific heat capacity, internal energy, pressure, thermodynamic processes); (2) Many materials in thermodynamic are lack in explanation and interpretation of phenomena and not linking them to daily life; (3) Unclear mathematics sign of work dan heat and relationship between them. (4) Diversity of thermodynamics process namely isothermal, isobaric, isochoric, adiabatic with their mathematics expression. (5) Existence of several thermodynamics variables namely pressure, volume, temperature; (6) There are many mathematical expressions with multitude of symbols and units. These reasons are fact why thermodynamics is really difficult to be learned for student. Thus, it affects negatively the learning and teaching process.

CONCLUSION

The result of research was the same with previous research regarding the nature of difficulties faced physics and chemistry undergraduate students. Most of the students in this study do not fully understand common thermodynamics concepts. The level of understanding concept of thermodynamics both physics and chemistry undergraduate student is still low. This because there are many difficulties in learning the concept of thermodynamic especially the ambiguity of concepts. The reasons of difficulties had been revealed as follows: (1) The concepts of thermodynamic are abstract physical concepts; (2) The matters of thermodynamics are lack in explanation and interpretation of phenomena and not linking them to daily life; (3) Ambiguity sign of work dan heat and relationship between them. (4) Diversity of thermodynamics transformations; (5) Existence of several thermodynamic variables; (6) There are many mathematical expressions with multitude of symbols and units.

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