Difficulties of Teaching and Learning the Concepts of Thermodynamics in the Secondary Education in Algeria

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(Received 25 November 2018, accepted 10 December 2018)

Abstract

This study deals with the difficulties of teaching and learning some of thermodynamics concepts programmed in the content of secondary education (its nature, types, causes). We used descriptive and analytical approaches. The study dealt with a sample of Algerian secondary students (third year secondary students - mathematical technical stream) in the final semester of the academic year (2012/2013), where 125 students were chosen for it. The tools selected for this study were: the tool of analyzing the content, testing thermodynamics concepts and interview with teachers. We have found many difficulties facing teachers in teaching some concepts such as heat and work, etc. and other difficulties facing students such as the existence of alternative perceptions to the students (eg: not differentiating between heat and temperature, absence of exchange of heat in the isothermal transformation). It has been shown that the reasons for these difficulties were diverse and the most important one is the lack of previous knowledge acquisition of students because they were not dealt with during the previous school years. Therefore, we recommend a review of the curricula and the necessity to incorporate a process linking and grading of the concepts through the various educational stages.

Keywords: Concepts of Thermodynamics, Alternative Perceptions, Secondary Education.

Resumen

Este estudio aborda las dificultades de la enseñanza y el aprendizaje de algunos conceptos de termodinámica programados en el contenido de la educación secundaria (su naturaleza, tipos, causas). Utilizamos enfoques descriptivos y analíticos. El estudio abordó una muestra de estudiantes de secundaria argelinos (estudiantes de tercer año de secundaria - flujo técnico matemático) en el último semestre del año académico (2012/2013), donde se eligieron 125 estudiantes para ello. Las herramientas seleccionadas para este estudio fueron: la herramienta para analizar el contenido, probar los conceptos de la termodinámica y entrevistar a los maestros. Hemos encontrado muchas dificultades que enfrentan los maestros al enseñar algunos conceptos como calor y trabajo, etc., y otras dificultades que enfrentan los estudiantes, tales como la existencia de percepciones alternativas a los estudiantes (por ejemplo: no diferenciar entre calor y temperatura, ausencia de intercambio de calor en la escuela). transformación isotérmica). Se ha demostrado que las razones de estas dificultades eran diversas y la más importante es la falta de conocimientos previos de los estudiantes porque no se abordaron en los años escolares anteriores. Por lo tanto, recomendamos una revisión de los planes de estudio y la necesidad de incorporar un proceso que vincule y califique los conceptos a través de las diferentes etapas educativas.

Palabras clave: Conceptos de termodinámica, percepciones alternativas, educación secundaria.

PACS: 01.50.Pa, 06.20.Jr, 07.60.Rd, 32.30.Jc **ISSN 1870-9095**

I. INTRODUCTION

Thermodynamics is considered as a branch of physics that is interested in studying the laws of the exchange of the various forms of energy, such as converting heat to work (steam machine) and converting work to heat (Joule experiment). It also describes and explains several processes and phenomena occurring in nature. This science emerged with the appearance of the steam machine and it's widespread during the industrial revolution in the late of 18th century. It was developed by physicists (such as Sadie Carnot, James Joule, James Watt, William Thomson, kelvin, Helmholtz, Gibbs).

The application of thermodynamics in chemistry led to the emergence of chemical thermodynamics in the late of 19th century by "Gibbs", which studies energy exchange in chemical reactions. It also appeared the thermochemistry branch which is interested in measuring the absorbed heat or the released one during the chemical reactions.

Thermodynamics is currently taught in the Algerian secondary education as an essential theme in the subject of technology for the third-year students, process engineering where the study is only limited to the first principle of thermodynamics " the conservation of energy", but is transformed from one form to another" [1, 2, 3], and its applications in Thermochemistry (the law of Hess). It has been shown through our practice of the teaching profession and the survey of the views of the teachers that there are many difficulties facing secondary school students as well as teachers in the thermodynamics. Some previous studies showed that there are many obstacles among university students in the application of the Hess' scheme [4], difficulties in applying the first principle of thermodynamics in physics [5], the existence of alternatives perceptions to the students about heat, temperature and pressure [6, 7], mystery in the concept of heat [8], and difficulties in teaching and learning chemical thermodynamics [9]. Students also face several problems in understanding the various processes of ideal gas [5]. Through historical study [1] it was shown that these difficulties are not newly made, but faced and puzzled even the greatest scientists and philosophers through the different ages, and contradicted the different ideas and theories such as:

-Confusing and not discriminating between the concept of heat and the concept of temperature.

-The stability of temperature when changing the physical states (fusion, evaporation ...).

-The contradicting theories about the nature of heat (substance theory and dynamic theory).

-Phlogiston theory.

-Mystery of the concept of energy.

II. PROBLEM OF STUDY

Through the practice of the teaching profession and the proclamation of teachers and students through personal interviews with them as well as the results of the evaluation tests, it shows that both teachers and students in the different high schools face great difficulties in this subject due to the existence of several obstacles that prevent the understanding and assimilation processes. To address the difficulties facing both teachers and students in thermodynamics and finding its causes, we formulate the problem of study in the main question:

What are the difficulties of teaching and learning the concepts of thermodynamics in the Algerian secondary education?

It has the following sub-questions:

1. What are the difficulties facing secondary school teachers in teaching the concepts of thermodynamics?
2. What are the difficulties facing secondary school students in learning the concepts of thermodynamics?
3. What are the causes of the difficulties facing teachers and students in thermodynamics?

III. METHODOLOGY AND PROCEDURES

Study approach:
In this study we used descriptive and analytical methods (describing the difficulties facing both teachers and students and analyzing their causes).

The sample of the study:
The study was applied to several secondary schools (11 high schools) in Algiers, in the final semester of the academic year (2012/2013), where there were (125) students (third year secondary students - mathematical technical stream, specialty of engineering process).

Study tools:

-Testing of the concepts of thermodynamics.

-Interview with teachers.

a) Testing of the concepts of thermodynamics:
Using the concepts of thermodynamics, as well as the tests that have been tackled by [4, 5, 10], test was prepared to diagnose the difficulties facing students in thermodynamics, which consists of 27 paragraphs, divided into three parts:

Part One: Multiple choice questions with four alternatives, at least one correct alternative followed by a justification.

Part two: Multiple choice questions with four alternatives, all are about the same shape that represents isothermal expansion for ideal gas process with a justification.

Part three: It consists of some definitions of the concepts of thermodynamics and writing some equations.

The test was followed by an additional question (No. 28) for giving opinions on the difficulty of thermodynamics.

The truthfulness of the test was checked by presenting it to a group of university professors and high school teachers specialized in physical sciences, who gave their opinions about the test to reach its final form after modification. (Annex)

The stability of the test was examined by calculating the coefficient of stability alpha (α) Kronbach estimated at α = 0.7 which confirmed the validity of the test for the application.

b) Teachers' interview:
We also interviewed 15 teachers specialized in engineering process to diagnose the difficulties faced by teachers as well as to find an actual opinion poll and observations on the process of teaching thermodynamics for the third-year high school students.

IV. SEARCH RESULTS AND DISCUSSION

Results of the first question:
The first question states:

What are the difficulties facing secondary school teachers in teaching the concepts of thermodynamics?

During the interview, we have diagnosed the difficulties faced by teachers in teaching the concepts of thermodynamics through the teachers' answers who teach engineering process. The teachers' opinions in teaching thermodynamics are shown in the following table:

TABLE I. Teachers' opinions in teaching thermodynamics.

Teachers' answer	*Difficult*	*Average*	*Easy*
Percentage (%)	40	53,33	6,66

It is graphically represented as follows:

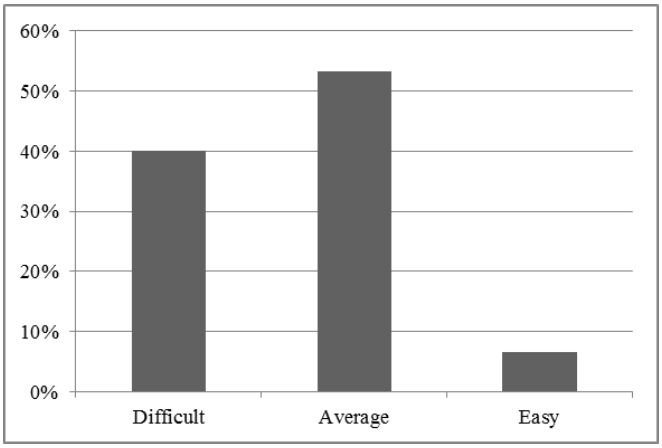


FIGURE 1. Percentage of the teachers' opinions in the teaching of thermodynamics.

The majority of teachers (93.33%) stated that the process of teaching thermodynamics is not easy (from average to difficult). With regard to the nature of the difficulties facing the teaching process, they are classified as follows:

1. Concepts:

-The difficulty of teaching some concepts: (Heat, work, temperature, specific heat capacity, enthalpy, internal energy, state function, ideal gas, adiabatic Transformation, isolated system, etc.).

-Difficulty of explaining the relationship between work and heat.

-The difficulty of linking the concept of work to the concept of energy.

-Difficulty of explaining the properties and conditions of ideal gas.

2. Primary phenomena and principles:

The difficulty of explaining and interpreting some of thermodynamics phenomena for the students such as:

-Constancy of internal energy and heat exchange in the isothermal transformation.

-Stability of temperature during the change of state of the material.

-Conversion of heat to work or vice versa.

3. Laws and measurements:

-Multitude of relations and mathematical laws due to the diversity of systems and transformations.

-Difficulty to explain the difference between the thermal capacities at the constant volume (C_v) and at constant pressure (C_p).

-Difficulty of measuring the specific heat of change state experimentally.

-Difficulty to illustrate the Hess scheme for some chemical reactions.

-Diversity of symbols and unit.

-Difficulty of solving some activities.

Results of the second question:

The second question states:

What are the difficulties facing secondary school students in learning the concepts of thermodynamics?

We have diagnosed the difficulties faced by students in learning the concepts of thermodynamics which represent an obstacle in comprehension and acquisition through the analysis of students' answers in the test of thermodynamic concepts.

The students' opinions in learning thermodynamics in the additional question (No. 28) are shown in the following table:

TABLE II. The students' opinions in learning thermodynamics.

Answer students	*Difficult*	*Average*	*Easy*
Percentage (%)	64,8	30,4	4,8

It is graphically represented as follows:

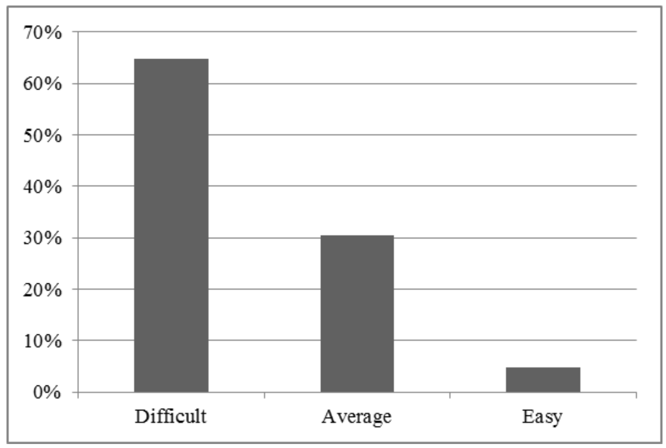


FIGURE 2. Percentage of students' opinion in learning thermodynamics.

The majority of pupils (64.8%) stated that learning thermodynamics is difficult. With regard to the nature of the difficulties, it was found through the analysis of students' answers that:

Difficulty to understand the concepts, as the answers to question (No 25) on the definition of some concepts are as follows:

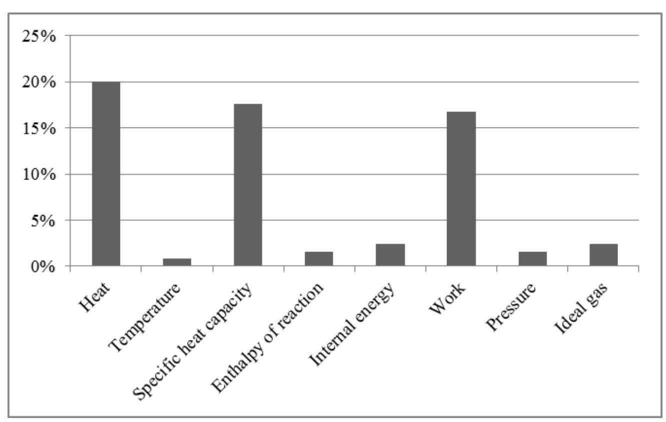


FIGURE 3. Percentages of surdents' correct answers in defining the concepts.

TABLE III. Shows the percentages of correct answers for students in defining the concepts

Number	*Concept*	*Percentage of correct answers for pupils (%)*
1	Heat	20
2	Temperature	0,8
3	Specific heat capacity	17,6
4	Enthalpy of reaction	1,6
5	Internal energy	2,4
6	Work	16,8
7	Pressure	1,6
8	Ideal gas	2,4
Correct answer rate		7,9

It can be illustrated graphically:

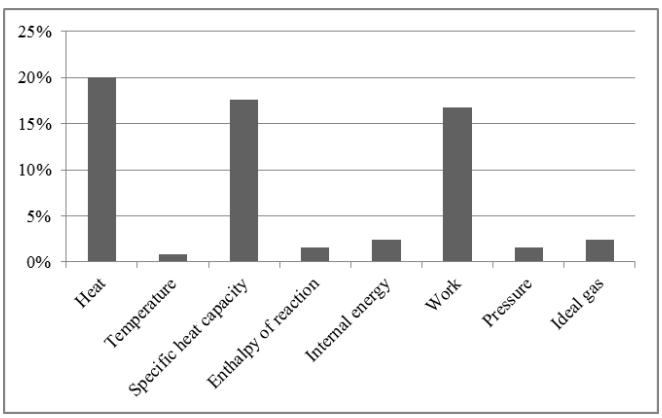


FIGURE 3. Percentages of students' correct answers in defining the concepts.

Comment:

By analyzing the results of Table 3 and Graph 3, it is found that the percentage of correct answers on the definition of some basic concepts is low from 0.8 % to 20 % (correct answer) which indicates a very weak control in the basic concepts of students' thermodynamics, precisely the following concepts: Temperature (only 0.8 % of pupils gave the correct answer), enthalpy of reaction and pressure (1.6 % correct answer), ideal gas (2.4 %). This weakness is confirmed by 26.66 % of the teachers - in the sample of the interview - as shown in the previous studies.

There were also several misconceptions about these concepts to the pupils. Table IV contains examples of these alternative concepts, which were deduced from the justification of the choice of the correct answer.

TABLE IV. Misconceptions of the students about thermodynamics.

Concept	*Description of some of the misconceptions*
temperature	The temperature is the hot of body
	Temperature change during a change of state
	Confusion between the temperature and degree Celsius
Heat	Heat is a substance that flows from hot objects to cold objects
	It is considered that the hot objects have heat in their internal energy
	Not differentiating between heat and temperature
	No heat exchange in the isothermal transformation
Specific heat capacity	Minerals have the same specific heat capacity
	Specific heat capacity of the matter is constant and does not relate to the temperature
	Specific heat capacity of the ideal gas is constant in all conditions
Enthalpy of reaction	Enthalpy of reaction is the heat reaction in all conditions
	Not differentiating between enthalpy of formation of chemical compound and enthalpy of formation of chemical bond
Internal energy	Internal energy is a chemical energy possessed by the particles of matter.
	Internal energy is the sum of heat and work
	No change in the internal energy of matter in its change state
	Constancy of the internal energy in the isolated system only
	The energy of the reactors is always equal to the energy of the products
Work	Work is not a form of energy
	Work at constant pressure equals the work at a constant temperature
	There is no relationship between work and heat
Pressure	Pressure is the result of gas expansion or contraction
	Pressure is resulted from collisions of gas molecules with each other
Ideal gas	Ideal gas is an imaginary gas that does not exist in nature
	Ideal gas is the gas found in the normality conditions
	Not differentiating between ideal gas and real gas

7,9

Table IV shows the existence of many misconceptions and alternative conceptions of secondary school students about the concepts of temperature, heat, specific heat capacity, enthalpy of reaction, internal energy, work, pressure, ideal gas. Examples of misconceptions and alternative conceptions of the students about the concept of temperature and heat: the temperature is the hot of body, which is due to the environment surrounding the student and the common expressions in the community, where the hot objects are expressed by their high temperature, cold objects by increase the degree of coolness , and extreme hot weather in the summer and extreme cold in the winter .They also do not differentiate between heat and temperature, as most of them consider heat and temperature as one concept, while the two concepts are different. Heat is a form of energy produced by the movement of molecules and atoms of matter whereas temperature is a measure of the average kinetic energy of atoms and molecules [10]. They also believe there is no exchange of heat in the isothermal transformation as well as the occurrence a change in temperature during the change of state of matter (eg: melting ice). This perception may be due to the ordinary observation of the phenomenon where ice melting requires the absorption of heat, which makes them believing that the temperature is rising. They do not realize that the absorbed heat changes the solid ice into liquid water because the liquid energy is greater than the solid energy.

Concerning of the concept of specific heat capacity, students think, for example, that metals have the same specific heat capacity as iron and coppe, ie, they require the same period to heating them to the same temperature because they rely on the observation or sense of touch only. They also consider that the specific heat capacity of matter is constant regardless of temperature, while specific heat capacity is a function of temperature, for example: The temperature needed to raise the water temperature from 298 K to 299 K is different from the temperature needed to raise the water temperature from 373 K (Kelvin) to 374 K although the difference is 1 K in both cases.

As for the concept of enthalpy of reaction, students do not check that it is the heat molar at a constant pressure, because they do not realize that the heat exchange changes at constant volume and pressure change. They do not also distinguish between enthalpy of formation of a chemical compound (energy forming a chemical compound from its pure elements) and enthalpy of formation of the chemical bond (the energy of forming the chemical bond in the gaseous state).

With regard to the concept of internal energy, students have alternative perceptions. They consider it as a chemical energy possessed by the particles of matter or the sum of heat and work because they do not understand the mathematical expression of the first principle of thermodynamics which states that the change in the internal energy of the system is equal to the sum of the heat exchange and work with the surrounding. However, internal energy is the sum of kinetic energy (resulting from the movement of particles) and latent energy (resulting from the attraction between particles) of matter. They also believe that the internal energy is constant in the isolated system only and not in other cases like the stability of temperature, or the equality of heat and work, or a closed cycles of system.

The concept of work is confusing for pupils as they do not understand that work is a form of energy and its value at constant pressure is different from that at constant temperature.

There are also alternative conceptions about pressure as students link the concept of pressure to the process of expansion or contraction of gas because of their misunderstanding of the relationship between these concepts. Some students consider that the pressure is caused by the collisions of gas molecules among them only, but they neglect the collisions of the gas molecules with the internal wall of the vessel which produce pressure.

As for perfect gas, students consider it as an imaginary gas that is not found in nature and ignore that it is a real gas found in special conditions (at high temperatures and low pressures). This perception may be acquired from the term "ideal" which is transmitted to them by some teachers who have the same perception. They also do not understand the existence of two different types of specific heat capacity of the ideal gas at constant pressure C_p and specific heat capacity at constant volume (C_v).

•It was found from experiments in practical work classes and test's results that the students have difficulties in performing some skills and competencies, such as:

-Confusion between the types of systems (open, closed, isolated).

-Confusion between the types of transformations (isothermal, isobaric, isochoric, adiabatic).

-The difficulty of recognizing the type of energy exchanged between the system and the surrounding as well as identifying its signal.

-lack of control of certain terms (such as isothermal transformation and adiabatic transformation)

-Confusion between spontaneous and non-spontaneous transformations.

-Confusion between physical and chemical transformations.

-Confusion between exothermic and endothermic reactions.

-Non-distinction between enthalpy reaction and enthalpy formation.

-Difficulty in applying the first principle of thermodynamics.

-Committing errors in measuring temperature experimentally (the way to hold and read the thermometer).

-Committing errors in using the calorimeter.

-Weakness in interpreting natural and experimental phenomena.

• The students also stated the following difficulties:

1. Concepts:

- Thermodynamics contains complex concepts and terms that are difficult to understand (work, heat, temperature, specific heat capacity, internal energy, pressure, enthalpy, bond energy).
- Ambiguity of the nature of work and heat, the difference of their signs and the recognition of the relationship between them.
- Non-distinction between the energy of forming a chemical compound and a chemical bond.

2. Phenomena:

- Difficulty to understand energy exchange between the system and the surrounding.
- Use of imaginary and unreal models (ideal gas, isolated system).
- Diversity of systems (open system, closed, isolated).

- Difficulty of distinguishing between the isolated system and the adiabatic system.
-Diversity of transformations (transformation of isothermal, isobaric, isochoric, adiabatic) and its different laws.
-Non-discrimination between heat exchange at constant pressure and at constant volume.
-Difficulty in understanding how to measure experimentally latent heat of ice fusion.

3. Laws and calculation:

-Thermodynamics depends on mathematics (mathematical relationships and long operations).
-Existence of several variables (pressure, volume, temperature).
-Multiple of work's expressions (depending on the type of transformation).
-Difficulty of calculating some quantities such as work, heat and internal energy due to the diversity of systems and transformations.
-Difficulty of calculating enthalpy reaction using bonds energies.
-Multitude of symbols and units.
-Multitude and similarities of laws, and therefore difficulty in choosing and applying the appropriate law to do the different activities.

We conclude that the difficulties encountered by both teachers and students cannot be separated because they are related to each other. The difficulties facing teachers hinder the understanding of their students, in contrast, the ones faced by students exhaust the teacher and affect negatively the process of teaching.

Results of the third question:

The third question of the study states:

What are the causes of the difficulties facing teachers and students in the thermodynamics?

To find the reasons for the difficulties we have done:

A) Opinion poll of teachers and students:

•According to the opinion poll of teachers - who teach engineering process - during the interview, they express the reasons for the difficulties as follows:
-Lack of previous acquisitions of pupils (most of the concepts are new to them).
-Difficulty to grasp the concepts of this subject by students because they are abstract concepts.
-Thermodynamics depends on the concept of energy, which is an abstract and complex concepts.
-According to the program, there is a lack in explanation and interpretation of phenomena and not linking them to daily life.
-Lack of time devoted to this axis.
-Weakness in controlling the Thermodynamics concept by some teachers.

•About (33 %) of teachers stated that Thermodynamics is not suitable for the cognitive development of high school students. The majority of them (93.33%) found that most students had few previous acquisitions about Thermodynamics. And (73.33%) of them believe that the program is incomplete and some of them (46.66%) believe that laboratory experiments carried out in this field (4 lab work only) are not sufficient because of the absence of experiments that illustrate the relations between scientific concepts such as: the relationship between heat and work and the relation of work with the internal energy. In addition, there is a lack of chemicals and experimental means in educational institutions (declared by 93.33% of teachers).

It was found that one of the reasons for the difficulties mentioned before is that some teachers are specialized in biochemistry and not in chemistry.

•On the other hand, students attributed the reasons for the difficulties in learning thermodynamics to the following factors:

a. The nature of thermodynamics:
-Inactive and boring as other fields (organic chemistry, biochemistry).
-Requires a lot of concentration.
-Depends on mathematics (mathematical relations and long and exhausting operations).
-Depends on memorizing the law.
-The subject of thermodynamics is very difficult and can't be understood.

b. Program:
-This topic is not linked to everyday life phenomena in the teaching process.
-This topic is new for students and has no relation with the lessons learnt in the previous years.

c. Means:
-Lack of chemicals and experimental means which facilitate the understanding.
-Insufficiency of activities in the textbook.

B) Analysis of Algerian curricula and textbooks:

We conducted a comprehensive analysis of some of the modern and old textbooks for the secondary stage (Maths mathematical technical and experimental sciences). The topics related to the Thermodynamics were concluded as follows:

TABLE V. Topics of old school textbooks for "Physics" from 1982 to 1987 [11, 12, 13].

Book of physics - First year secondary education *School year: 1982/1983*
- Different cases of matter - Pressure in solid objects - Fluid balance - Atmospheric pressure: existence – measurement - Temperature concept – Expansion of objects with high temperature - Gas contraction: Boyle's – Mariotte's law - Gay-Lussac's law– Charles' law / General equation of gases - Kinetic theory of gases - The amount of heat - Energy
Book of physics - First year secondary education *School year: 1986/1987*
- Pressure in fluids - Pressure measurement - Temperature - Expansion of objects - The amount of heat
Book of physics - Third year secondary education

School year: 1985/1986	
THERMODYNAMICS	
The first principle in thermodynamics	- Basic information in thermodynamics and exchange between the heat and work - The principle of equivalence between work and heat - Initial and final state of a system in transformation - Internal energy
The second principle in Thermodynamics	- Thermal motors - Second principle in thermodynamics (Kelvin principle - Carnot principle) - Productivity of thermal machines - Conservation of energy

TABLE VI. Topics for modern curricula and textbooks for "Physics" for the academic year 2012/2013 [14, 15].

Program of physics - Second year secondary education School year: 2012/2013	
Energy	- Qualitative approach to energy of system and its conservation - Work and kinetic energy - Potential energies - Internal energy - Energy and citizenship
Matter and its transformations	Ideal gas law: A method for measuring the amount of substance in the gaseous state
Program of Engineering Process Third year secondary education (mathematical technical stream) School year 2012/2013	
Thermodynamics	- Systems in thermodynamics: the amount of heat and mechanical work - First Principle of thermodynamics - Applications of the first principle of thermodynamics: calculation of enthalpy reaction (Hess Law)

Comment:

By comparing the contents of the old and modern curricula and programs of physics and engineering process for secondary education, it has shown as follow:

* The concepts of thermodynamics were present in detail in the old curriculum of physics for the first-year secondary education, where specific lessons were planned (eg: pressure, temperature, amount of heat, gases, and states of matter). Thermodynamics is then taught in a detailed way in the program of physics for the third years, where it deals with some preliminary information (such as the principle of equivalence between work and heat). After that, it gets into the basic themes in Thermodynamics (eg: Principle I, Principle II, and Thermal Motors).

*For modern programs and curricula: The basic themes and concepts of thermodynamics are completely absent in the first-year secondary program. As for the second-year secondary program, the concept of energy is related to mechanics (kinetic energy and potential energy) and converted from one form to another to reach the principle of the conservation of energy. It links the concept of work to kinetic energy (mechanical work). The concept of change in internal energy has been used in the case of heat exchange only in the stability or change the physical state of the matter. It has never tackled the exchange of energy in the form of mechanical work (work of pressure forces) in the case of expansion and contraction of ideal gas and the occurrence of change in the internal energy when doing a work. Some thermal measurements were also programed by using the calorimeter in order to measure the specific heat capacity of matter or calorimeter.

*In analyzing the topic of ideal gases, it is given a superficial definition. It is proved experimentally the relationship of: pressure of gas with its volume at a constant temperature (Boyle-Mariotte's law), pressure with temperature at a constant volume (Charles' law), volume with temperature at a constant pressure (Gay-Lussac's law), and pressure with number of moles at constant temperature and volume , in order to produce the law of ideal gas by which we calculate the number of gas moles. However, the importance of this law was not mentioned in the calculation of partial pressures or work. The basic concepts (heat, temperature, pressure, work, internal energy, specific heat capacity, gases ...) were not programed in special and detailed lessons in comparison with the ones in the old curricula, but only superficially.

*In the modern curriculum, the topic of thermodynamics is taught only in the third year - mathematical technical stream - without a previous acquisition of students on this subject. It deals with the first principle of thermodynamics and its applications (calculation of enthalpy reaction using Hess law) with a neglect of detailed basic concepts such as: (ideal gas, heat and temperature). Besides, the curriculum did not insert the lessons of steam machines to explain the relationship between work and heat.

These facts make it difficult for students to grasp the thermodynamics phenomena surrounding them due to the absence of basic concepts. Thus, it affects negatively the learning and teaching process.

V. CONCLUSIONS

The results of the present study were identical with the results of the previous studies regarding the nature of the difficulties faced by secondary school students, as well as the existence of alternative perceptions similar to those of university students. But the study was also unique in diagnosing the nature of the difficulties faced by the teachers. The findings were as follows**:**

There are many difficulties in teaching and learning the concepts of thermodynamics, the most important of which is the ambiguity of concepts.

The causes of the difficulties were diverse, the most important ones are:

-The concepts of thermodynamic are abstract physical concepts.
-The students do not have previous acquisition about thermodynamics.
-The existence of acquired alternative perceptions to students.
-Lack of knowledge of some teachers on thermodynamics.

IV. RECOMMENDATION

According to the findings of the study, a number of recommendations were suggested:

1.- Teaching some of the concepts of thermodynamics in the first and second years of secondary education which must be done in a coherent and gradual way according to the cognitive development of students.
2.- Teaching this topic throughout the year or at least at the beginning of the school year, as well as increase in the timing devoted to it.
3.- Modification of the curriculum and textbook by addressing the deficiencies and simplification of concepts, as well as the inclusion of concrete examples corresponding to the level of the students' knowledge.
4.- The need to link the theoretical part and practical part with the phenomena surrounding students.
5.- Intensifying and diversifying the activities by taking into account their gradation.
6.- Addition of other lessons (such as steam machine and the second principle of thermodynamics).
7.- Addition of some lab works (eg: experiments that show the relationship between work and heat) and provision of means and materials necessary to perform them.
8.- Planning scientific visits to factories that apply the principles of thermodynamics in industry.
9.- Preparation of teachers by training them on thermodynamics.
10.- The necessity of linking the previous knowledge with the new ones during the preparation of the curricula to achieve the objectives of the teaching and learning processes.

IIV. REFERENCES

[1] Sénéchal, D., *Histoire des sciences*, Notes de cours, PHQ-399, (Université de Sherbrooke, UK, 2001).
[2] Hertz, J., *Historique en grandes enjambée de la thermodynamique de l'équilibre*, J. Physque **IV**, 122 (2004).
[3] Amiot , P., *Thermodynamique* , département de physique, de génie physique et d'optique, (Université Laval, Québec, Canada, 2006).
[4] Barlet, Roger, Mastrot, G., *L' algorithmisation – refuge, obstacle à la conceptualisatio L' exemple de la thermochimie en 1er cycle universitaire*, Didaskalia **17**, 123-159 (2000).
[5] Meltzer, D. E., *Investigation of students' reasoning regarding heat, work , and the first law of thermodynamics in an introductory physics course*, Am. J. Phys. **72**, 1432-1446 (2004).
[6] Sozbilir, M., *A Review of Selected Literature on Students' Misconceptions of Heat and Temperature,* J. Educ. **20**, 25-41 (*Bogaziç University*, 2003).
[7] Pathare, S, Pradhan, H. C., *Student' Alternative Conceptions in Pressure, Heat and Temperature*, Trends in Sci. Educ. Res, 38-41 (India, 2005).
[8] De Jong , O., *How to teach the concept of heat of reaction: a study of prospective teachers' initial idea*, J. *Chem. Educ*. **1**, 91-96 (1999).
[9] Le Maréchal, J. F., El Bilani, R., *Teaching and Learning Chemical Thermodynamics in School*, Int. J. of Thermodynamics **11**, 91-99 (2008).
[10] Zimmermann, M. L., *Concept de chaleur; contribution a l'étude des conceptions d'élèves et de leurs utilisation dans un processus d'apprentissage*, Thèse de doctorat, (Université de Genève, FPSE 172, 1990).
[11] Ministry of National Education., *Textbook of physics,* First year secondary education, Algeria, (1982).
[12] Ministry of National Education., *Textbook of physics,* Third year secondary education, Algeria, (1985).
[13] Ministry of National Education., *Textbook of physics,* First year secondary education, Algeria, (1986).
[14] Ministry of National Education., *Curriculum of physics,* Second year secondary education, (Algeria, 2012).
[15] Ministry of National Education., *Curriculum of Engineering Process*, Third year secondary education mathematical technical stream, Algeria, (2012).

ANNEX

Testing thermodynamic concepts

I. Choose the correct answer, then tick (X) in the appropriate column with justification:

1.- Heat is:
a) An energy transformed to other forms
b) An energy not transformed to other forms
c) not a type of energy
d) an unknown nature
justification:………………………..……………………
2.- Work is:
a) An energy transformed to other forms
b) An energy not transformed to other forms
c) not a type of energy
d) an unknown nature
justification:………………………..……………………
3.- The statement of work for ideal gas - contained in a closed cylinder with a moving piston - relates to:
a) Type of system
b) Type of transformation
c) Type of matter
d) Time of transformation
justification:
4- The difference in temperature between two connected systems - containing pure water - leads to:
a) Heat exchange

b) Work exchange
c) Heat exchange and work
d) Exchange of substance
justification:……………………..……………………

5.- Heat exchange between pure water (liquid) and surroundings at constant pressure leads to :
a) Temperature change with stability of physical state of water
b) Temperature stability while the physical state of water remains constant
c) Temperature stability with changing of physical state of water
d) Change of temperature with physical state of water
justification:……………………..……………………

6.- Be $\Delta U = 0$ - always - in:
a) Opened system
b) Closed system
c) Isolated system
d) Adiabatic system
justification:……………………..……………………

7.- Specific heat capacity of water relates to:
a) Amount of heat
b) Temperature
c) Water mass
d) Water volume
justification:……………………..……………………

8.- The temperature of two contacted bodies T_1 and T_2 and their specific heat capacity C_1 and C_2, respectively. The final temperature T at the thermal equilibrium is related to:
a) Temperature T_1 and T_2 only
b) Thermal capacity C_1 and C_2 only
c) Temperature T_1 , T_2 and specific heat capacity C_1 , C_2
d) Other conditions
justification:……………………..……………………

9.- The heat absorbed by the system is zero ($Q = 0$) in :
a) Transformations at constant temperature (isothermal)
b) Transformation at constant volume (isochoric)
c) Transformation at constant pressure (isobaric)
d) Adiabatic transformations
justification:……………………..……………………

10.- At adiabatic transformations of ideal gas :
a) $Q = 0$
b) $W = 0$
c) $\Delta U = 0$
d) $\Delta H = 0$
justification:……………………..……………………

11.- In adiabatic transformations is:
a) T is constant with P and V are variables
b) P is constant with T and V are variable
c) V is constant with T and P are variable
d) T, P, V are variables
justification:……………………..……………………

12.- During the reversible transformation , the relationship between internal pressure (P_{sys}) and external pressure (P_{ex}) of the system is:
a) $P_{ex} = P_{sys}$
b) $P_{exsys}P \neq$
c) $P_{ex} > P_{sys}$
d) $P_{ex} < P_{sys}$
justification:……………………..……………………

13.- The variation of state function is related to:
a) Primary state only
b) Final state only
c) Primary and final states
d) Other conditions
justification:……………………..……………………

14.- Enthalpy formation and enthalpy reaction are:
a) Always equal
b) Sometimes equal
c) Are not equal at all
d) Unknown relationship
justification:……………………..……………………

15.- To calculate enthalpy reaction with the application of the Hess law, we must :
a) Make the experiment of the reaction itself
b) Do not Make the experiment of the reaction itself
c) Use the values of enthalpy of other reactions
d) Calculate the values of enthalpy of other reactions experimentally
justification:……………………..……………………

16.- In the ideal gas :
a) The volume of the gas compared to the volume of the pot is: neglected or considerable
b) The attractions between the gas molecules are: neglected or considerable
c) Potential energy: $Ep = 0$ or $Ep \neq 0$
d) Kinetic energy : $Ec = 0$ or $Ec \neq 0$
justification:……………………..……………………

17.- Are the following reactions occurring spontaneously or non-spontaneously?:
a) Astra reaction (organic acid + alcohol) : spontaneous or non-spontaneous
b) Electrolysis of water: spontaneous or non-spontaneous
c) $(Zn^{2+}{}_{(aq)} + SO_4^{2-}{}_{(aq)}) + Cu_{(s)}$: spontaneous or non-spontaneous
d) $(Cu^{2+}{}_{(aq)} + SO_4^{2-}{}_{(aq)}) + Zn_{(s)}$: spontaneous or non-spontaneous
justification:……………………..……………………

18.- Are the following physical transformations exothermic or endothermic? :
a) Fusion: exothermic or endothermic
b) Freezing : exothermic or endothermic
c) Condensation: exothermic or endothermic
d) Evaporation: exothermic or endothermic
justification:……………………..……………………

19.- Are the following transformations chemical or physical?:
a) Combustion of wood : physical or chemical
b) Fusion of ice : physical or chemical
c) The expansion of ideal gas : physical or chemical
d) The reaction of Sodium with water : physical or

chemical
justification:………………..……….…………………

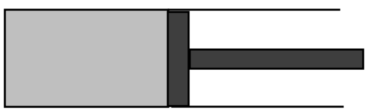
20.- Find the type of the following systems (open system / closed system / isolated system):

a) Refrigerator: open or closed or isolated
b) Light bulb: open or closed or isolated
c) Candle burning: open or closed or isolated
d) Thermos bottle: open or closed or isolated
justification:……………………..……………………

II. The system consists of 1 mole of ideal gas found inside a closed cylinder with a moving piston.
The gas has an isothermal reversible expansion as in the following figure:

Primary state (B): (P_i , V_i , T_i)

A



Final state (B) : (P_f , V_f , T_f)

B

21.- What happens to the following gas quantities during this process (transfer from state A to B? :

a) temperature
b) Volume: increases or decreases or stabilizes
c) Pressure: increases or decreases or stabilizes
d) Internal energy: increases or decreases or stabilizes
justification:……………………..…………………

22.- During this process (transfer from state A to B), the work is :

a) Done by the system (gas) on the surroundings
b) Done on the system (gas) by the surroundings
c) There is no work done from the system or on the system
d) I do not know
justification:…………………..……………………

23.- During this process (shift from state A to B), is the work done on the system?:

a) Positive
b) Negative
c) None
d) I do not know
justification:……………………..……………………

24.- From the first principle of thermodynamics, is the heat exchanged between the system and the surrounding in the transfer from state A to B:

a) Positive
b) Negative
c) None
d) I do not know

III. Answer the following questions**:**

25.- Define each of the following:

a) Heat……………………………………………….….
b) Temperature……………………………….…….
c) Specific heat capacity …………………………….
d) Enthalpy reaction …………………………………
e) Internal energy………………………………………
f) Work………………………………………………..
g) Pressure……………………………………………..
h-Ideal gas……………………………………………..

26.- Give the statement of the first principle of thermodynamics and its mathematical law:
………………………………………………….

27- Write equation reaction to the formation of the following compounds:

a) $Al_2O_{3\ (s)}$: …….……….…………...………………..
b) $SO_{2\ (g)}$: …………………………………………..
c) $Fe_{\ (s)}$:…………………….……………………….
d) $C_2H_5OH_{\ (l)}$: …………………………………………..
justification:…………………….…………………

28.- After studying the thermodynamic axis, do you think it is ? :

a) Difficult
b) Easy
c) Average

The reasons: …………………………………………..
…………………………………………………………
…………………………………………………………