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A study of some challenges of learning and teaching thermodynamics concepts in university education in Algeria

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ABSTRACT

This study addressed the challenges students face in learning thermodynamics concepts in higher education in Algeria, focusing on their nature, causes, and types. The study adopted a descriptive and analytical approach and targeted university students majoring in chemistry and physics during the academic year 2024/2025. The sample included 112 students who were randomly selected. The study used tools such as questionnaires, interviews with faculty members, and field observations within classrooms to collect data. The results showed significant difficulties in understanding basic concepts such as internal energy, the relationship between heat and work, enthalpy, and entropy. We also observed that students have difficulty distinguishing between theoretical principles and their practical applications, with misconceptions about thermodynamics concepts. The results also revealed a weakness in students' mathematical background and prior knowledge, which complicates the subject. Based on these findings, the study recommended revising curricula to include interactive practical applications that link theoretical and applied concepts, in addition to improving teaching methods.

Keywords: Thermodynamics concepts, learning difficulties, university education, alternative conceptions, teaching methods

INTRODUCTION

Thermodynamics is one of the fundamental branches of science and engineering, as it deals with the study of energy and its transformations in physical and chemical systems (Smith et al., 2018). Understanding the principles of thermodynamics enables us to grasp the concepts and apply them in our daily lives, including internal combustion engines and refrigeration and air conditioning systems (Van Wylenand et al., 2019), in addition to understanding natural phenomena such as climate cycles and biological processes (Woldamanuel et al., 2015).

Students face many difficulties in learning and comprehending thermodynamics concepts, which negatively affects their academic achievement and their ability to correctly understand phenomena (Atkins and De Paula, 2010).

Thermodynamics heavily relies on the use of mathematical equations to analyze systems and understand phenomena. However, research indicates that many students lack sufficient mathematical skills to effectively apply these relationships (Çengel and Boles, 2019). Moreover, thermodynamics concepts are characterized by complexity and abstraction, which makes them difficult to understand for many students (Saricayir et al., 2016, p.11). Acquiring these concepts requires a high level of analytical and mathematical thinking, such as the concepts of heat quantity, work, and the concept of entropy or free energy (Tsokos, 2014). In addition, students often find it difficult to link theoretical concepts with

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practical applications, which increases the difficulty of their comprehension of the subject (Dukhan, 2016).

Among the common difficulties students face in learning thermodynamics is the challenge of understanding the three laws of thermodynamics and applying them to problem-solving (Landsberg, 1990), particularly the application of the first law of thermodynamics. Many misconceptions among students have been identified and diagnosed regarding the concepts of heat, temperature, and pressure (Douadi et al., 2018), which is due to their lack of deep understanding of fundamental concepts such as internal energy, heat, and work.

Many previous studies related to the first law of thermodynamics have documented students' difficulties with thermodynamic processes and variables (Brown and Singh, 2022). Students often confuse similar concepts such as heat and temperature or internal energy and enthalpy, and this confusion reflects a lack of clarity in their understanding of basic concepts (Driver et al., 1994).

Thermodynamics requires an understanding of thermal processes at the microscopic level, such as the movement and interactions of molecules (Chandler, 1987), and many students find it difficult to visualize these processes, which hinders their deep understanding of the subject.

Students often struggle to connect theoretical concepts with practical applications in the fields of engineering and chemistry (Felder and Brent, 2016). This lack of connection between concepts makes the subject seem abstract and unrelated to their reality (Brown and Singh, 2022).

Language is considered another factor that contributes to hindering the learning of thermodynamics (Lin S. Y. and Singh C., 2015). Some of the language-related issues include unfamiliar and misleading vocabulary (Coletta V. P. and Phillips J. A., 2005). It was found that for second-language learners, the usable working memory space was reduced by about one unit, which could have been used to process language transfer (Beichner R., 1994). In the United States, one researcher observed that the challenges students face in learning chemistry may not necessarily be related to the subject itself but rather to the way it is presented and discussed (Singh C. and Rosengrant D., 2003). The findings included the use of teachers' words that were not accessible to their students.

These difficulties negatively affect students' achievement in thermodynamics and may lead to decreased motivation and lack of self-confidence (Zoller, 1990). Poor understanding of thermodynamics may impact students' ability to apply these concepts in their academic and professional fields, hindering their development and progress in the fields of engineering and science.

Computer-based simulation education, where students can use software to observe thermodynamic changes in virtual environments, contributes to clarifying complex concepts in a visual and interactive manner (Dincer and Rosen, 2020). Studies have also shown that using real-life applications and practical examples helps connect theoretical concepts to real-life contexts, facilitating understanding and comprehension (Moran et al., 2014).

In addition, the problem-solving approach is considered one of the effective methods, where students are asked to analyze real thermodynamic problems and find appropriate solutions. This method helps develop critical thinking and enhance applied understanding (Bejan, 2016).

Studies in Algeria have shown that many difficulties in learning and teaching thermodynamics concepts have been diagnosed (Ben Batka, 2018) among both teachers and students at the middle and secondary education levels (Ben Batka, 2021). A set of misconceptions and alternative conceptions has also been observed among university students (Douadi et al., 2018). However, little work has been done on thermodynamics at the university level.

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Given the importance of thermodynamics and its impact on many fields, research into the difficulties of learning and teaching it is of great significance. This study aims to analyze the difficulties students face in learning thermodynamics concepts and to identify the factors influencing these difficulties. It also aims to develop effective teaching strategies that help students overcome these difficulties and improve their understanding of the subject.

By analyzing the difficulties and identifying the influencing factors, innovative teaching strategies can be developed to improve the quality of thermodynamics education. These strategies may include the use of interactive educational tools such as computer simulations and virtual experiments (Bao and Koenig, 2019), and the application of active learning methods that encourage students to participate effectively in the learning process (Prince, 2004).

Purpose of the Study:

This study aims to identify and diagnose the learning and teaching difficulties related to topics and concepts of thermodynamics among university students in the faculties of exact sciences at Algerian universities, and to determine the reasons why students find these topics and concepts difficult.

The following research objectives were investigated:

- To identify and classify the learning and teaching difficulties of thermodynamics principles experienced by university students in chemistry and physics majors.
- To determine the reasons why students find it difficult to learn the principles of thermodynamics.

Problem Statement:

Through the practice of teaching, as well as interviews with teachers and students and the analysis of test results, it

becomes evident that both teachers and students across various universities face significant difficulties with this subject due to numerous obstacles that hinder processes of understanding and comprehension. To address these difficulties and identify their causes, the problem of the study is formulated in the following main question:

What are the difficulties in learning and teaching thermodynamics concepts in Algerian universities?

The following sub-questions arise from it:

- What are the difficulties university students face in learning thermodynamics concepts?
- What are the causes of the difficulties students face in thermodynamics?
- What are teachers' views on methods to improve learning and overcome the obstacles encountered in learning thermodynamics topics?

Methodology and Procedures:

This research aims to study some of the challenges students face in learning thermodynamics topics related to the laws of thermodynamics and their fundamental concepts such as enthalpy, entropy, heat quantity, and work.

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The sample for this study consists of students from the Faculty of Exact Sciences and Computer Science at the University of Djelfa, and students from the Faculty of Technology at the University of Laghouat. Participants were recruited from two organic chemistry classes comprising approximately 112 students.

To accurately examine the challenges students face in learning thermodynamics, data were collected using multiple methods. Data collection involved a Likert-type questionnaire, a thermodynamics concepts test, and interviews with students and teachers.

1. Likert-Type Questions:

Several Likert-type questions were developed with the aim of helping us gain a better understanding of some of the challenges students face in learning thermodynamics.

2. Interviews with Students and Teachers:

We conducted interviews with second- and third-year university students majoring in physics and chemistry after they had studied thermodynamics courses and related topics. We also conducted interviews with a group of professors specialized in these subjects to diagnose the difficulties faced by instructors, as well as to obtain actual feedback and observations regarding the process of teaching thermodynamics to undergraduate students.

3. Thermodynamics Concepts Test:

Based on the thermodynamics concepts included in the first- and second-year courses for science and technology students at Algerian universities, a test was developed to diagnose the difficulties students face in thermodynamics. The test consists of 18 items divided into two parts:

- **Part One:** Includes definitions of thermodynamics concepts and writing of some equations.
- **Part Two:** Multiple-choice questions with four alternatives, at least one correct option followed by a justification.

Following the test, questions were included to gather opinions on the applications of thermodynamics in daily life and on teaching methods that could help enhance students' achievement and understanding of these topics. By analyzing their views and suggestions, it becomes possible to identify the obstacles that hinder student learning and work toward finding solutions to overcome these challenges. The validity of the test was verified by presenting it to a group of university professors and secondary school teachers specialized in physical sciences, who provided their feedback on the test, leading to its final form after revision.

The reliability of the test was examined by calculating Cronbach's alpha coefficient (α), which was estimated at $\alpha = 0.7$, confirming the test's suitability for implementation.

Table 1: Likert-Type Survey Questions to Assess Students' Understanding of Thermodynamics Topics and Concepts.

1. I understood the first law of thermodynamics well after studying it.
2. I can solve problems related to the ideal gas without difficulty.
3. The teaching method used helped me understand the first law of thermodynamics.
4. I feel confident in my ability to apply the first law of thermodynamics in problem-solving.

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5. At first, I had difficulty understanding the concepts of enthalpy and entropy.
6. The teaching method used was effective in clarifying the role of entropy in thermal processes.
7. I now feel confident in my ability to explain entropy and use it to analyze thermal systems.
8. I had difficulty understanding the relationship between enthalpy and entropy when determining spontaneity.
9. The teaching method used helped me understand the relationship between enthalpy and entropy.
10. I can now easily explain spontaneity using the concepts of enthalpy and entropy.
11. I was able to solve problems related to thermal systems easily after studying the course.
12. The practical applications presented during the course helped me connect theoretical concepts to thermodynamics.

The Likert-type questions section included 13 items measured on a scale ranging from "Strongly Disagree" to "Strongly Agree." The Likert-type questions were recorded on a five-point scale ranging from (1) Strongly Disagree, (2) Disagree, (3) Neutral, (4) Agree, and (5) Strongly Agree. The questions are listed in Table 1.

Questions 1, 2, and 3 relate to the first law of thermodynamics. Questions 4 and 6 are related to the concept of entropy. Questions 7 and 8 concern the determination of reaction spontaneity and its relationship with enthalpy and entropy. Questions 5, 8, 11, and 12 relate to the effectiveness of teaching methods and the acquisition of concepts for solving thermodynamics-related problems

Results and Discussion:

Results related to the first question: What are the difficulties university students face in learning thermodynamics concepts

We diagnosed the difficulties students face in learning thermodynamics concepts that constitute obstacles to understanding and acquisition by analyzing students' responses to the thermodynamics concepts test.

Through the Likert-type questionnaire, students' views on learning thermodynamics are presented in the following table:

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Table 2: Analysis of Students' Responses to Likert-Type Questions on Learning Thermodynamics Concepts

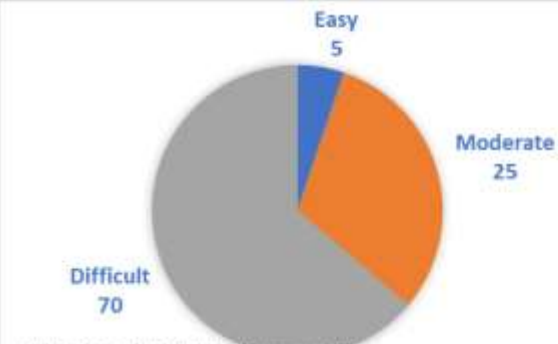


FIGURE 1: PIE CHART OF STUDENTS' RESPONSES REGARDING THE DIFFICULTY OF LEARNING THERMODYNAMICS

Percentage(%)	'Students Responses
Less than 5%	Easy
Less than 25%	Moderate
More than 70%	Difficult

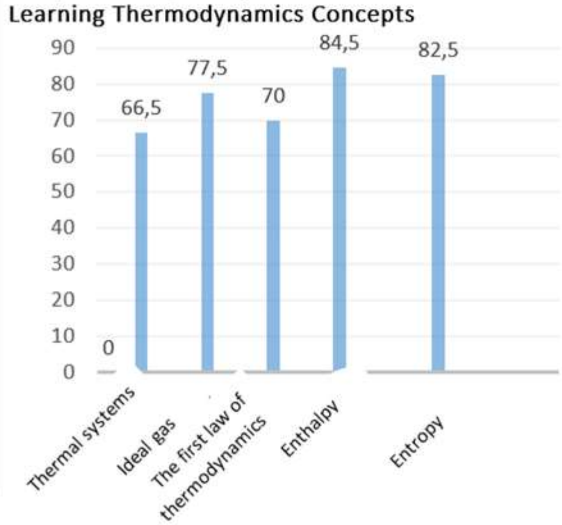
Figure 1 represents a pie chart illustrating students' responses regarding the perceived difficulty of learning thermodynamics topics.

The results show that the majority of students (64%) consider thermodynamics to be one of the most difficult subjects during their studies.

Through the analysis and statistical evaluation of the Likert questionnaire responses related to the learning of thermodynamics topics and concepts, percentage values were identified for the difficulties related to thermal systems, problems involving the ideal gas, the first law of thermodynamics, and the relationship between reaction spontaneity and enthalpy and entropy.

Table 3: Percentage Analysis of Students' Responses According to the Difficulty of Concepts

Figure 2: Percentage of Students' Responses Regarding Difficulties in Learning Thermodynamics Concepts



No.	Concept / Idea	Percentage (%) of Responses Related to Learning Difficulties
1	Thermal systems	66.5
2	Ideal gas	77.5
3	The first law of thermodynamics	70
4	Enthalpy	84.5
5	Entropy	82.5

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Table 3 and Figure 2 illustrate the percentage values concerning the difficulties and challenges students face in learning thermodynamics concepts, ranging from 65% to 85%, indicating a very weak grasp of the fundamental concepts of thermodynamics among students.

The results reveal poor conceptual acquisition, particularly regarding **thermal systems**, which were rated as the least difficult by students, with a percentage of **66%**. For concepts related to the **first law of thermodynamics**, the percentage was **70%**; for the **ideal gas**, **77.5%**; for **entropy**, **82.5%**; and for **enthalpy**, **84.5%**.

This study describes the common difficulties students face in thermodynamic processes, variables, and thermal systems. The findings align with previous studies, thereby supporting the validity and robustness of earlier results, although based on a broader range of questions posed in different contexts.

Table 4 shows the existence of several misconceptions and alternative conceptions among university students regarding the concept of the ideal gas and the concepts related to the laws of thermodynamics, such as **internal energy**, **heat quantity**, **work**, and the concepts of **enthalpy** and **entropy**. According to item 1 in the questionnaire related to the ideal gas, students consider it an imaginary gas that does not exist in nature, ignoring the fact that it is a real gas that exists under specific conditions (at high temperatures and low pressures). This misconception may stem from the term *"ideal"*, which is conveyed to them by some instructors who hold the same belief.

Table 4: Misconceptions About Some Thermodynamics Concepts Among Students

Concept	**Some Misconceptions**
Ideal Gas	Some believe that the molecules of an ideal gas are stationary and do not move. The ideal gas is an imaginary gas that does not exist in nature. An ideal gas undergoing an isothermal process results in a change in the system's internal energy.
Internal Energy	Confusion between internal energy and free energy. Internal energy is the chemical energy possessed by the molecules of a substance. Confusion between internal energy and mechanical energy. There is no change in the internal energy of a substance during its phase change.
Work	Work at constant pressure is equal to work at constant temperature. The work done by the gas is positive even if the volume of the system does not change. Work is zero (W = 0) in a constant pressure process.
Enthalpy	Confusion between enthalpy and heat quantity. Some believe that enthalpy is the same as the internal energy of the system. Failure to distinguish between the energy of formation of a chemical compound and the bond formation energy.
Entropy	Entropy must always increase within the system itself. Entropy is related only to temperature. Confusion between the change in enthalpy and the change in entropy, and between endothermic and exothermic reactions in determining the spontaneity of transformations.

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Thermal Systems and Transformations	Heat transfers only from hot objects to cold ones. Some believe that isothermal transformations do not require any heat exchange with the surroundings. Confusion between isothermal transformations and adiabatic transformations.

Many students did not know (or did not recall) the relationship between internal energy and the heat of an ideal gas, and therefore did not recognize its importance when solving problems that required this information. This often meant that their problem-solving process went off track.

One common difficulty concerns items 9 and 10, related to the ideal gas undergoing an isothermal process, which led students to conclude that the internal energy of the system would change during such a process. This difficulty was often due to the fact that students assumed the heat quantity $Q=0$ for an isothermal process. When these students applied the first law of thermodynamics under the assumption that $Q=0$, they arrived at a non-zero value for the change in internal energy during the isothermal process.

As for energy, interviews indicated that some students do not distinguish between internal energy and free energy. For example, students experiencing this confusion claimed that, in order to reach equilibrium, the system tends to lower its internal energy. Another commented: “The system tends toward greater entropy and a lower internal energy state.”

Some students used the terms "energy" and "internal energy" interchangeably, and some even confused free energy with potential energy. For example, one student observed that entropy (S) favors a state of disorder and considered that higher entropy corresponds to lower potential energy.

It was also found that some students did not distinguish between the internal energy of the system and its mechanical energy. One student incorrectly claimed that in a cyclic process, the work done by the system is zero and thus the internal energy of the system is conserved. He concluded that when potential energy increases, kinetic energy decreases so that the total internal energy remains unchanged.

Regarding the difficulties with state variables in cyclic processes, the majority of students believed that all thermodynamic quantities return to the same value after a cycle (such that $Q=0$ and $W=0$ in cyclic processes). One justification given by a student was: “Since internal energy and entropy are state variables, they remain unchanged, i.e., $\Delta U=0$ and $\Delta S=0$, after a complete cycle because the system’s initial and final states are the same.”

Similar to previous research, it was found that students faced common difficulties in using the mathematical definition of work during interviews. Students often tried to use a quantitative description of work, which frequently led to difficulties in solving problems, particularly those related to the first law.
Students who approached the problem using conceptual reasoning generally performed better than those who focused solely on the mathematical formula when applying the first law.

In items 7, 8, and 13 of the questionnaires, students were asked whether the values of the work done by the system, the internal energy of the system, and the system’s entropy are determined for a given thermodynamic system by the state of the system or by the process that led to that state. Nearly 70% of the students gave incorrect answers to these questions.

Many students believed that the work done by the gas is positive in free expansion or in spontaneous processes such as heat transfer from one subsystem to another or the mixing of gases in two chambers, even if the total volume of the system does not change (item 13).

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Some interviewed students thought that no heat exchange occurs between the system and the surroundings without referring to the system's state.

Students were asked about the relationship between the system's state and the process that led to that state in relation to the values of the work done by the system, its internal energy, and its entropy in a given thermodynamic system. More than half of the students provided incorrect answers to this question. In items 2, 5, and 10 concerning the enthalpy of reaction, students did not distinguish between internal energy and enthalpy at constant pressure or volume, as they did not realize that heat exchange changes depending on whether volume or pressure is held constant.

In items 11 and 12, the percentage of correct answers was less than 25%, and students did not distinguish between the energy of formation of a chemical compound (the energy required to form a compound from its pure elements) and the energy related to bond formation (bond formation energy in the gaseous state).

Regarding entropy, in items 14, 15, and 16 of the questionnaire, students were asked about the conditions under which entropy decreases and about identifying reactions characterized by a positive value of entropy. More than 65% of the students gave incorrect answers, and they were unable to relate the concept of entropy to the spontaneity of transformations.

From the test results and interviews, it can be concluded that students face difficulties in performing certain skills and competencies, such as:

- Integrating different types of systems (open, closed, isolated).
- Difficulty in applying the first law of thermodynamics and in understanding, analyzing, and explaining certain natural and practical phenomena.
- Inability to distinguish between types of transformations (isothermal, isobaric, isochoric, adiabatic).
- Inability to differentiate between heat exchange at constant pressure and constant volume.
- Difficulty in identifying the type of energy exchanged between the system and its surroundings.
- Inability to distinguish between bond energy and the energy of formation of a chemical compound.
- Confusion between spontaneous and non-spontaneous transformations.

Results Related to the Second Question: What Are the Causes of the Difficulties Students Face in Thermodynamics?

Through the interviews conducted to gather the opinions of instructors teaching thermodynamics topics, they expressed that the challenges and difficulties are related to a set of reasons, including:

- Weak mastery of the concept of thermodynamics by some teachers.
- The large number of abstract concepts that students are required to deal with and establish relationships between.
- Around 80% of the teachers confirmed that most students have a significant lack of prior knowledge related to thermodynamics concepts, and 70% of them believe that the curriculum is incomplete. Some (40%) believe that laboratory experiments conducted in this field are insufficient due to the lack of experiments that demonstrate relationships between scientific concepts.

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- A shortage of chemicals and experimental materials in educational institutions (reported by 93.33% of teachers).
- One of the reported reasons for the difficulties is that some teachers are not specialized in thermochemistry, which negatively affects their performance.
- Student frustration, failure, and lack of motivation due to the difficulty of constructing new knowledge in thermodynamics and linking it to prior concepts, as students face many new abstract ideas that they must master in a short time. This volume of knowledge does not allow for full understanding and assimilation of abstract concepts.
- The persistence and development of thermodynamics misconceptions among students from middle and secondary education to university level, due to the failure of some textbooks to clearly distinguish between certain concepts, such as internal energy and heat.
- Most teachers believe that the learner's cognitive structure for a given body of knowledge is likely influenced by the organization of that body of knowledge, and that the learning process is largely affected by how new ideas are first introduced, indexed, and stored in memory, which contributes to deep learning. The cognitive structure in the brain is largely responsible for the learner's ability to solve problems.

Results of the Third Question:

What are the teachers' and students' views on methods to improve learning in order to overcome the obstacles they face in learning thermodynamics topics?

The teacher must take into account the way in which the learner acquires knowledge and adjust their teaching to align with human learning patterns in particular.

Through the conducted interviews, it became clear from the opinions of the majority of teachers that teaching thermodynamics is not easy (ranging from moderate to difficult). As for the nature of the difficulties encountered in the teaching process, they relate to several key factors, including:

- Difficulty in teaching certain concepts such as internal energy and work, the ideal gas, various thermal transformations, thermal systems, etc., and in explaining the relationship between work and heat, as well as the concepts of work and energy.
- Difficulty in explaining and interpreting certain thermodynamic phenomena for students, such as the constancy of temperature during a phase change.
- The abundance of mathematical relationships and laws due to the variety of systems and transformations, along with the inability to solve some problems and exercises.
- Variation and inconsistency in symbols and units.

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Table 5 and Figure 3 show the analysis of teachers' opinions regarding the level of difficulty in teaching thermodynamics concepts.

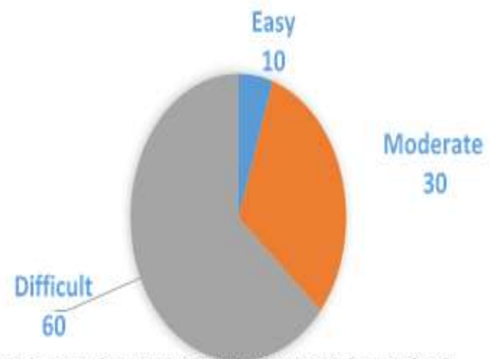

FIGURE 3: PIE CHART OF TEACHERS' OPINIONS ON THE DIFFICULTY OF TEACHING THERMODYNAMICS TOPICS

'Teachers Responses Regarding the Difficulty of Teaching	(%) Percentage
Easy	Less than 10%
Moderate	Less than 30%
Difficult	More than 60%

We recorded students' opinions on the effectiveness of teaching methods for thermodynamics concepts by analyzing their responses in the thermodynamics concepts test.

Through the Likert questionnaire, students' views are presented in the following table:

Table 2: Analysis of Students' Responses Regarding the Effectiveness of Teaching Methods in Their Acquisition of Thermodynamics Concepts

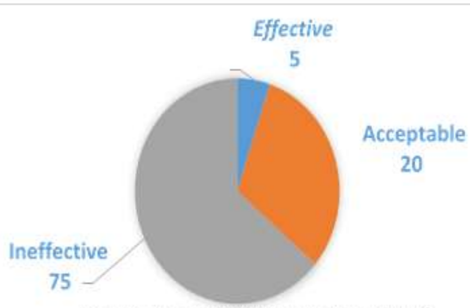

FIGURE 4: PIE CHART OF STUDENTS' OPINIONS ON THE EFFECTIVENESS OF THERMODYNAMICS TEACHING METHODS

Teaching Effectiveness	Percentage (%) of Students' Responses
Effective	Less than 5%
Acceptable	Less than 20%
Ineffective	More than 75%

Regarding the question addressed to students about the appropriate methods and approaches to enhance their understanding and achievement in thermodynamics topics, the majority of students emphasized the use of practical experiments, simulations, and modern technological tools.
The results of this study aligned with those of previous research concerning the nature of difficulties encountered by middle and high school students, where similar misconceptions to those held by university students were found. This indicates that students do not possess a deep conceptual understanding of thermodynamics topics and face numerous challenges in learning these concepts. Studies show that rote learning and memorization do not lead to effective learning, and that teaching thermochemistry courses based on traditional lectures occurs passively, with very little student participation in the learning process, which reduces their motivation and interest.

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The findings suggest a need to change teaching methods and strategies related to topics such as heat, pressure, enthalpy, entropy, and the ideal gas.

Students should be more actively involved in the learning process and provided with ample opportunities to build their new knowledge in a deeper and more accurate manner. This can be achieved by using active learning and constructivist teaching methods more consistently in college-level instruction. Adopting diverse learning styles and environments will better enable students to develop a strong understanding of thermodynamics concepts.

CONCLUSION

Through the experimental approach, this study identified the following key concepts from thermodynamics topics that students find difficult to understand. The results of the current study were consistent with those of previous studies concerning the nature of alternative conceptions held by university students, although they differed in some concepts compared to the secondary level. However, the study varied in the percentages and causes of these conceptions. The findings can be summarized as follows:

- The research data confirms the need to improve education and enhance teaching methods to overcome the challenges of learning thermodynamics concepts.
- Students hold several misconceptions and alternative conceptions about thermodynamics.
- Students do not have sufficient prior knowledge to build new concepts in thermodynamics.
  - The main causes of alternative conceptions are related to the educational environment and curricula, as well as the absence of practical and applied aspects in the teaching of thermodynamics concepts.

Recommendations

Based on the results of the study, a set of recommendations has been proposed as follows:

- Training teachers by providing them with instruction in thermodynamics.
- Including thermodynamics topics in the curriculum that are closely related to students' real-life experiences and environments, and ensuring the connection between prior knowledge and new knowledge when designing curricula to achieve teaching and learning objectives.
- Revising the curriculum and textbooks at the middle and secondary education levels by addressing deficiencies and simplifying concepts to include concrete examples that align with the knowledge level of university students.
- Teaching thermodynamics concepts at the pre-university level in a coherent and gradual manner in accordance with students' cognitive development.
- Incorporating laboratory work (e.g., experiments illustrating the relationship between work and heat) and providing the necessary tools and materials to carry them out.
- Organizing scientific field trips to factories that apply thermodynamics principles in industry.
- Further work is needed to understand the challenges faced by students and teachers in learning and teaching thermodynamics topics.

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ANNEX

Testing thermodynamic concepts

Part One: Define the following concepts

1. The ideal gas is defined as: ....
2. Enthalpy is defined as: ....
3. Entropy is defined as: ....

4 – Write the statements of the three laws of thermodynamics and their corresponding mathematical expressions:

- **First Law: ....**
- **Second Law: ....**
- **Third Law: ....**

Part Two: Choose the correct answer for each question, then place a check mark (√) in the appropriate box, and provide a justification for your answer — if applicable.

(**Important Note:** Each question has only one correct answer.)

5 – The change in Enthalpy is:

A) The sum of heat and work

B) The molar heat at constant volume

C) The molar heat at constant pressure

D) The molar heat at constant temperature

6 – The change in internal energy is:

A) The change in Enthalpy

B) The molar heat at constant volume

C) The molar heat at constant pressure

D) The molar heat at constant temperature

Justification:

7 – The change in internal energy in adiabatic transformations is equal to:

A) Heat quantity

B) Work

C) The sum of heat quantity and work

D) The sum of temperature and work

Justification:

8 – The system does not exchange heat with the surroundings ($Q = 0$) in:

A) Isothermal transformations

B) Isobaric transformations

C) Isochoric transformations

D) Adiabatic transformations

Justification:

9 – The change in internal energy of an ideal gas is zero ($\Delta u = 0$) in the case of:

A) Isothermal transformations

B) Isobaric transformations

C) Isochoric transformations

D) Adiabatic transformations

Justification:

10 – The internal energy and Enthalpy of an ideal gas depend only on:

A) Temperature

B) Pressure

C) Pressure and temperature

D) Volume

Justification:

11 – Bond energy is:

A) The energy required to break the bond (in the gaseous state)

B) The energy required to form the bond (in the gaseous state)

C) The energy required to form (synthesize) a compound

D) The energy required to change the physical state

Justification:

12 –The energy of formation (synthesis) of a chemical compound is:

A) The energy required to break the bonds of the atoms in the compound

B) The energy released when the compound is formed from its simple elements

C) The energy released when the compound is formed from its compound elements

D) The energy required to change the physical state of the compound

Justification:

13 –The work done by an ideal gas contained in a closed cylinder with a movable piston depends on:

A) The type of system

B) The type of transformation

C) The type of gas

D) The time of the transformation

Justification: