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Research article

Four-Tier Thermodynamics Diagnostic Test (4T-TDT) to Identify Student Misconceptions

Yoga Budi Bhakti[1*], Irnin Agustina Dwi Astuti[1], and Rendi Prasetya[2]

[1]Program Studi Pendidikan Fisika Universitas Indraprasta PGRI, Indonesia
[2]Program StudiTeknik Informatka Universitas Indraprasta PGRI, Indonesia

Abstract.
There are limited studies on the diagnosis of thermodynamics misconceptions using a four-tier instrument diagnostic test. Therefore, this identifies the misconceptions in thermodynamics material. The survey research was conducted on 577 students at SMAN in Semarang, Central Java. Students were selected using a simple random sampling technique. Identification of student misconceptions was done using the Four Tier Thermodynamics Diagnostic Test (4T-TDT). Students' conceptual understanding was calculated using the percentage technique. The results of this study indicate that many students still have misconceptions about the concept of thermodynamics. The findings are expected to be a strategic step for designing appropriate remedial teaching.

Keywords: thermodynamics, misconception, four-tier diagnostic test, alternative conception

Corresponding Author: Yoga Budi Bhakti; email: bhaktiyoga.budi@gmail.com

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1. Introduction

One of the most common issues in the physics of education is a misconception[1]. Until now, this misconception is still often experienced by students. Misconceptions are not only experienced by students in Indonesia [2,3,4,5,6], but also occur in many other countries [1,4,7,8,9]. Misconceptions occur at various levels of education, ranging from elementary school[10,11,12], junior high school[13,14], senior high school [15,16], undergraduate[17,18] and postgraduate school[19,20]. Misconceptions that occur in students will have a bad impact on understanding advanced concepts that are more complex so that it takes handling of students who had misconceptions.

Misconceptions are thoughts, ideas, or explanations about a phenomenon that are not supported by the physical principles that the student accepts[21,22]. Some literature uses different word choices for misconceptions. Other terms misconceptions areal: alternative conceptions, conceptual difficulties, misunderstandings and others[23,24]. Of the various terms used in some literature, misconceptions or alternative conceptions are the more common terms used today. Physical experience, direct observation, intuition, teaching in school, outside of school, social environment, culture, language, textbooks, or other teaching materials, and teachers can all contribute to students' misconceptions[19].

In the field of education, especially physics subjects, the misconception of student physics almost occurs in various materials[6,25,26,27,28,29]. One of the most interesting physics materials to research related to student misconceptions is thermodynamics. Thermodynamics is fundamental physical matter. The misconception of physics in thermodynamic materials is urgent to study because it will have an impact on the mastery of other materials. In addition to being used in physics, thermodynamic materials are also used in chemistry and engineering, related to kinetic gas theory and the efficiency of a machine.

Many other studies about the misconceptions of student physics in thermodynamic matter [30,31,32,33,34]. However, some studies have limitations in diagnosing student physics misconceptions on thermodynamic materials with 4-tier instruments. The four tier diagnostic test is a development of a three tier diagnostic test, on a four tier diagnostic test having an additional level of student confidence in the reason for choosing an answer. Although the three tier diagnostic are less accurate in detecting misconceptions of student [35]. However, because the students' confidence levels at the first and second levels are not distinguished, it still has limits[36].

On the three tier diagnostic test, students were asked about confidence in the first and second stages at the same time. The three tier diagnostic test was less accurate in detecting misconceptions. This is due to the level of confidence in the first and second stages of being asked simultaneously. This can lead to students being too low in interpreting and proportions not yet understood concepts. The advantage of a four tier diagnostic test is that the confidence level at the first and second levels is asked separately, so the analysis of the combination of answers on the four tier diagnostic test is more specific or more pronounced compared to the three tier diagnostic test[35]. In addition, the four tier diagnostic test is more specific or clearer in grouping categories of concept understanding, not understanding concepts, misconceptions or errors.

Based on the results of the initial survey related to the misconception of physics to 577 students of grade XI at senior high school in Semarang obtained data that from 577 students who filled out questionnaires expressed many do not understand the material thermodynamics, with details as many as 114 students or 19.8% admitted to understand while as many as 463 students or 80.2% admitted not understanding. Therefore, the author feels interested in identifying misconceptions in thermodynamic matter experienced by students. As is well known, students' misconceptions are unique to them. This implies that the types of mistakes made by students differ from one another. One of the strategic phases in designing improvement-oriented education is to do research. This research aims to identify the misconceptions of physics in thermodynamic materials to high school students in Semarang using Four Tier Thermodynamics Diagnostic Test (4T-TDT).

2. Methods

This research uses survey research design conducted at High School in Semarang to grade XI students. The study included 577 students as respondents. Respondents were selected using a simple random sampling technique.

To determine the misconceptions of student physics in thermodynamic materials used the Four Tier Thermodynamics Diagnostic Test (4T-TDT). The question point of thermodynamic test has gone through the validation stage and expert tests that state that the instrument to be used is valid and reliable. The 4T-TDT instrument consists of four-tier. They were questions, answers, confidence levels of the answers, reasons, and confidence levels of the reasons. The four tier test diagnostic instrument framework is shown in Table 1. Figure 1 is an example of a 4T-TDT used.

Table 1: The four tier test diagnostic instrument framework.

The developed four tier test diagnostic instrument framework	
Question Option Option Option Option	Reasons toward the selected answer Option Option Option Option
The confidence level of the selected answer Confident Not confident	The confidence level of the selected reason Confident Not Confident

In Figure 1 is an example of a question of the 4T-TDT instrument, in this point between the level of confidence in answering the question on distinguished grounds. So that with the 4T-TDT instrument students can easily be grouped in categories of concept understanding, partial understanding, misconceptions and not understanding concepts. The criteria for assessing the level of conceptual understanding refer to Table 2. The distribution of the conceptual understanding of students as a whole, students with misconceptions and students with scientific knowledge, is calculated using the percentage technique.

Dua bejana A dan B volume yang sama berisi udara yang suhu dan massanya sama. Bejana A dipanaskan secara isobaris sedangkan udara di dalam bejana B dipanaskan pada proses isokhoris. Jika besar kalor yang diberikan pada bejana A dan B sama maka …

A. Perubahan energy dalam di A dan B sama
B. Kenaikan suhu udara di A dan B sama
C. Kenaikan suhu udara di A lebih kecil daripada di B
D. Kenaikan suhu udara di A lebih besar daripada di B

Tingkat keyakinan jawaban:
A. Yakin
B. Tidak Yakin

Alasan:
A. Karena bejana B usaha bernilai nol dan mengalami proses isokhorik sehingga kalor sepenuhnya untuk perubahan energy dalam, jadi suhu bejana B lebih besar.
B. Karena bejana A mengalami proses isokhorik sehingga kalor sepenuhnya untuk perubahan energy dalam, jadi suhu bejana A lebih kecil.
C. Karena bejana B kalor sebagian berubah menjadi usaha dan energy dalam, jadi suhu bejana B lebih kecil.
D. ………………………………………………………………………………………….....

Tingkat keyakinan alasan:
A. Yakin
B. Tidak Yakin

Figure 1: Example items in the 4T-TDT.

Table 2: Decision making for four-tier test.

1^{st} Tier	2^{nd} Tier	3^{rd} Tier	4^{th} Tier	Decision
C	CF	C	CF	U
C	CF	C	NCF	PU
C	CF	C	NCF	PU
C	CF	W	CF	PU
C	CF	W	NCF	PU
C	CF	W	CF	PU
C	CF	W	NCF	PU
W	CF	C	CF	PU
W	CF	C	NCF	PU
W	NCF	C	CF	PU
W	CF	W	NCF	NU
W	NCF	W	CF	NU
W	CF	W	NCF	NU
W	CF	W	CF	MISC

W = Wrong; C = Correct; CF = Confident; NCF = Not Confident; U = Understanding; PU = Partial Understanding; NU = Not Understanding; MISC = Misconception

3. Results and Discussion

The distribution of the number of students related to the understanding of the concept of physics in thermodynamic matter is shown in Figure 2.

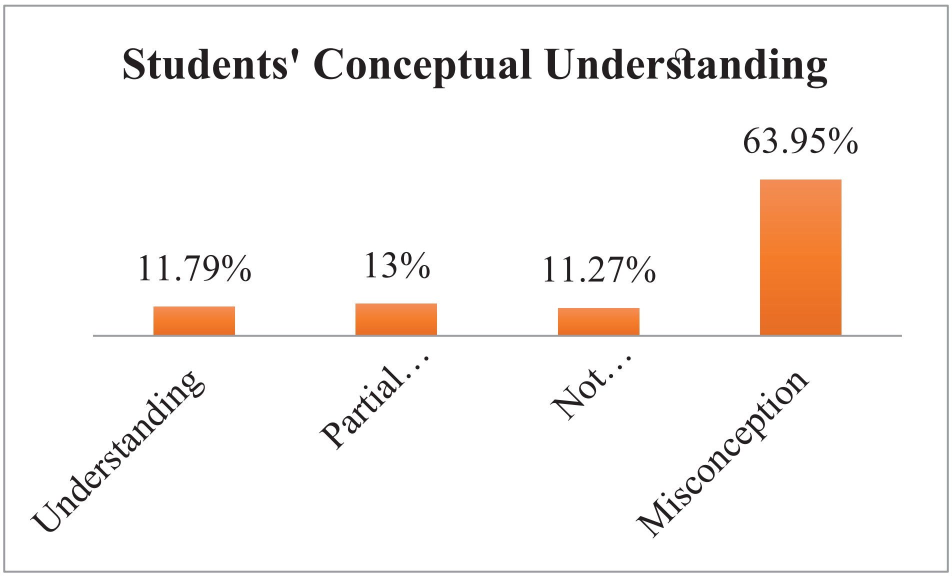

Figure 2: Distribution of students' conceptual understanding.

According to Figure 2, more than half of the respondents experienced a physical misconception of thermodynamic matter. The percentage of students who experience misconceptions is 63.95%, while consecutively the percentage of students who experience concept understanding, not understanding concepts and understanding concepts is partly 11.79%, 13 and 11.27%.

The visualization shown in Figure 2, it is known that the degree of misconception of student physics in thermodynamic matter shows a very high percentage. These results require further analysis to find out the part of the thermodynamic material that causes students to experience misconceptions.

Figure 3 shows the results of a more detailed identification of students who have misconceptions.

Based on Figure 3, students experienced the most misconceptions in item 1 at 66.93%. As many as 65.82% of students had misconceptions in item 2, 59.73% of students had misconceptions in item 3, 64.52% of students had misconceptions on item 4 and 62.78% of students had misconceptions on item 5. Item 1 "Interpreting the ideal gas pressure equation in an enclosed space" was the concept with the most misconceptions. As many as 66.93% experienced by students. While item 3 "understand the stages of the isobaris process" is the concept with the least misconceptions as much as 59.73%. but

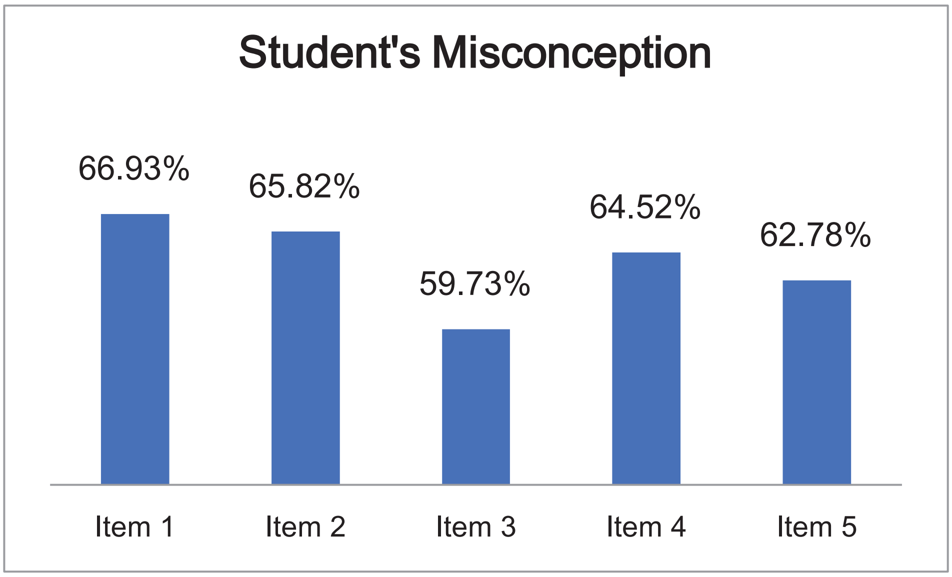

Figure 3: Students who experience misconceptions.

that percentage still falls into the high category for the degree of misconception of student physics on thermodynamics.

The purpose of this study is to determine the degree of misconception of student physics in thermodynamic materials using instruments 4T-TDT. The four tier instrument diagnostic test is an appropriate instrument to know the level of physics misconceptions [37], the results of this physics misconception will be categorized into 4, namely understanding concepts, not understanding concepts, understanding partial concepts and misconceptions. According to the results, the average student who had misconceptions had the highest level of conceptual ability compared to the other categories.

When viewed from the misconceptions of physics in thermodynamic matter, many students are more than 60% unable to interpret the ideal gas equation into a statement. The ideal gas equation... from this equation, if some variables are exchanged places between each other, the student is unable to interpret the change in the equation. Students also experience misconceptions about comparable and inversely proportional words. So in this item, many students answer incorrectly on level 1 and 3 questions, but believe correctly that the answer is correct. Because the concept that is understood is thought to be accurate, students who have misconceptions cannot be changed through conventional learning. Special treatment is required to minimize misconceptions. Teachers must provide outstanding learning experiences that can impact these students' perceptions and attitudes. A combination of interactive conceptual learning models and multimedia interactive learning models is one of the learning models that may be utilized to eliminate misconceptions[38].

Based on results and analysis, it is known that students' understanding of isobaric processes in thermodynamic cycles has the lowest level of understanding, but falls into a high category as well. Misconceptions on this item, students are often inverted between the cycle of the isobaric process and isokorik. Basically, an isobaric process is a thermodynamic process under fixed pressure while isokorik is a thermodynamic process with a fixed volume. In addition to the category of misconceptions, in this item also found other categories such as understanding concepts, understanding partial concepts and not understanding concepts. Comprehension partial concepts are when students' conceptual understanding is distributed. Understanding partial concept conditions happen when students don't understand why a concept applies but still believe it is correct.

Meanwhile, the not understanding concepts condition is a condition where students understand the reason for a concept to be valid but do not understand the existing concept's truth[39]. The terms understanding partial and not understanding concepts are also known as deficiency understanding and less information. Partial understanding concept conditions are more challenging to repair than not understanding.

This finding does not only occur in high school students but also at lower and higher levels of education as previously reported [12,14,29].

4. Conclusion

Based on the findings previously described, students still experience a misconception of the concept of "Interpreting the ideal gas pressure equation in an enclosed space" and "understand the stages of the isobaris process". On average, students who experienced misconceptions were 63.95%. These findings make a significant contribution to teachers who teach thermodynamic material. Teachers can use the outcomes of the identification process as a foundation for developing effective learning. For schools, it can support teachers in constructing multiple efficient learning models to reduce misconceptions. In terms of identifying students' conceptual knowledge, these findings are minimal. More research can be done to find out where the misconceptions come to originate.

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