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REMEDIATION OF THERMOCHEMICAL MISCONCEPTIONS USING A PROBLEM-BASED LEARNING MODEL BASED ON MULTIPLE REPRESENTATION

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Abstract

This research aims to describe students' misconceptions of thermochemical matter at SMAN 8 Pinrang, and then remediate these misconceptions using a problem-based learning model based on multiple representations. The research method used is descriptive analytics. The subjects of this research were class XI F1 students. The data collection instrument used a misconception test of three-tier multiple-choice thermochemical matter with 20 items and an interview guide. Data analysis was carried out using percentages. The research results show that misconceptions occur in the concepts of system and surroundings, exotherm and endotherm, standard enthalpy formation changes, and determining enthalpy changes based on Hess's law. The misconceptions that occur in these four concepts are 1) students identify the container as a system, 2) in exothermic reactions the temperature of the system will decrease because it releases heat into the surroundings, 3) standard formation reactions are identified as being formed from molecules or other compounds, 4) many The reaction stage can affect the magnitude of the enthalpy change. The average reduction in misconceptions for these four concepts was 44% in the medium category. The average reduction in misconceptions for each student is 43% in the medium category.
Key words: *Remediation of misconceptions, three-tier multiple-choice, problem-based learning model.*

INTRODUCTION

The characteristics of chemistry are: 1) Most of the concepts are abstract, hierarchical, structured, and simple; 2) the science of solving various problems and describing the facts of an event [1]. One of the goals that must be achieved in learning chemistry is that students can master the chemical concepts they have studied, and then students are expected to be able to relate these concepts to the matter being studied. Therefore, it is very important to emphasize mastery of concepts in chemistry learning.

Current learning tends to be student-centered, and this causes students to have difficulty understanding abstract and complex chemical concepts. Chemical matter must be understood in stages, if students do not understand the basic concepts, there will be the potential for misconceptions [2]. Misconceptions are discrepancies between students' understanding of concepts and scientific concepts formulated by scientists in their field [3]. Misconceptions about basic concepts or prerequisites result in students experiencing difficulties understanding the matter resulting in repeated or continuous misconceptions [4].

Students' initial understanding is an important variable in chemistry learning which is essential. If students' initial knowledge is not able to process new information, then students will have difficulty understanding subsequent matter, inaccurate reasoning, and ultimately misconceptions [5]. Thermochemistry is essential because it is closely related to rate of reaction, chemical equilibrium, and several other reaction concepts. There are interrelated concepts so if there are misconceptions about thermochemical matter, it is likely that there will also be misconceptions in other concepts [6].

The picture of thermochemical misconceptions is strengthened by the results of

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several studies which show that students experience high-category misconceptions regarding the concept of exothermic and endothermic reactions [7], [8], embedding systems and surroundings [7], [9], [10], the concept of determining the heat of decomposition based on binding energy [6], and thermochemical reaction equations [6], [11]. This shows that misconceptions are a barrier to the chemistry learning process. The burden of misconceptions carried by each student must be reduced by remediation. Remediation is an activity carried out to correct mistakes made by students or change students' conceptions that were originally wrong to be correct. Remediation activities aim to assist in the form of teaching treatment or guidance in overcoming cases faced by students that may be caused by internal or external factors.

Efforts to remediate misconceptions among students can be made through the Problem-Based Learning (PBL) model [12]. The PBL model is learning where students can solve scientifically authentic problems to actively compile students' knowledge and give meaning to the information and events experienced [13]. If students solve problems well, they can increase concept knowledge [12]. In the PBL model, students encounter several problems that arise, namely, students will have difficulty understanding the problems presented and have difficulty solving problems. Solving student problems can be overcome by providing cognitive assistance. Cognitive assistance will help students understand the problems presented and help solve problems [14]. One of the cognitive assistance that can be given to students is the use of the multiple representation method.

Multiple representation is a learning process that can be symbolized in an object or process. In chemistry, representations can take the form of images, diagrams, graphs, simulations, animations, and so on [15]. There are three main functions of multiple representations, namely as a complement to cognitive processes, helping to limit the possibility of misinterpretation and misconceptions, and building a deeper understanding of concepts. Understanding chemical concepts requires the integration of three levels of representation [16]: macroscopic, submicroscopic, and symbolic. The submicroscopic description is a conceptual level used to explain macroscopic phenomena, which will later describe more abstract particulate-level chemical phenomena. Understanding all three levels of representation is critical to understanding chemical phenomena, including thermochemistry involving mathematical equations, algorithmic capabilities, and interpretation.

Thus, the author conducted research with the title "Remediation of Thermochemical Misconceptions Using a Problem-Based Learning Model Based on Multiple Representation in Class XI Students of SMAN 8 Pinrang". The formulation of the problem in this research is: 1) What misconceptions do students experience regarding thermochemical matter? 2) What percentage of misconception reduction occurs after remediation.

METHOD

This type of research is analytical descriptive research which functions to describe or provide an overview of an object being studied through data or samples that have been collected as they are without carrying out analysis and making conclusions that apply to the general public. This research was carried out on subjects who experienced misconceptions about thermochemical matter, which was aimed at remediating these misconceptions through a PBL model based on multiple representations.

This research was carried out in the odd semester of the 2023/2024 academic year at SMA Negeri 8 Pinrang. The subjects in this research were 35 students in class XI F 1.

The instruments used in this research were a misconception test in the form of a three-tier multiple choice and a semi-structured interview guide. The misconception test aims to identify students' misconceptions about thermochemical matter consisting of 20 items. Before the misconception test instrument was used, a content validation test was first carried out by two expert validators, as well as item validation which was tried out on 26 students who had studied

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thermochemistry. The reliability obtained was 0.74 (tier 1) and 0.89 (tier 2) and the validity of each item in tier 1 ranged from 0.3 to 0.61 while tier 2 ranged from 0.3 to 0.6. Semi-structured interviews were conducted to explore the consistency of students' answers that had been chosen and to find out the reasons why students chose answers to test questions that had been carried out previously. Interviews with students were carried out after implementing the misconception test. Semi-structured interviews were conducted with 10 students from a selected stratified random sample.

The first misconception test was given after the teacher provided thermochemical matter. During learning with the teacher, the teacher uses a direct instruction model without any learning media. The results of the first misconception test were then analyzed to obtain data on students who experienced misconceptions and thermochemical concepts that had misconceptions. Then, misconception remediation learning was carried out using a PBL model based on multiple representations. Students who experience misconceptions are again given a second misconception test with the same questions to analyze the level of misconception reduction that occurs.

Students who experience misconceptions are determined from the scoring results by adjusting the criteria set by Arslan [17] as shown in Table 1. Distribution of student answers based on answer patterns, reasons, and level of belief. A correct first-level answer is given a score of 1, while an incorrect answer is given a score of 0. The second level is scored in the same way. The level of student confidence consists of three levels of response (sure, not sure, and guessing). The total score for the misconception test is 40.

Qualitative analysis is based on the pattern of answers of students who experience misconceptions according to the criteria in Table 1. These misconceptions are tabulated for each concept and calculated in percent. Determining the concepts that have misconceptions is done by making percentage items, then each item is put together based on a certain concept and then averaged. a concept is considered a general misconception if 20% or more of the research subjects believe it[18]. Analyzing students who experience misconceptions in thermochemical matter is also by the categories suggested by Al-Balushi, students experience misconceptions in general if the level of misconception is greater than or equal to 20% [18]. This stage is supported by data obtained from semi-structured interviews conducted with 10 students who consistently experienced misconceptions.

Table 1. Criteria for Student Conception

Tier-1	***Tier-2***	***Tier-3***	**Category**
Correct	Correct	Certain	Understand the concept
Correct	Correct	Not sure / Guessing	Understand the concept (not confident)
Correct	Wrong	Not sure / Guessing	Lack of understanding
Wrong	Correct	Not sure / Guessing	Lack of understanding
Wrong	Wrong	Not sure / Guessing	Lack of understanding
Correct	Wrong	Certain	Misconceptions (False Positive)
Wrong	Correct	Certain	Misconceptions (False Negative)
Wrong	Wrong	Certain	Specific Misconceptions

To determine the reduction in misconceptions for each student and the reduction in misconceptions for each concept, use a formula adapted from the normalized gain formula developed by Hake.

$$\text{RP} = \frac{\%\text{TM1} - \%\text{TM2}}{\%\text{TM1} - \%\text{ideal}} \times 100\%$$

Information:

RP = Individual/Concept Reduction (%)

%TM1 = Percentage of first misconception test (before remediation)

%TM2 = Percentage of second misconception test (after remediation)

%ideal = Ideal expectation of misconceptions (0%).

RESULTS AND DISCUSSION

A. Results

1. Percentage Reduction of Misconceptions for Each Student

30 students experience general misconceptions and 5 students do not experience general misconceptions regarding thermochemical matter (Figure 1). After remediation learning, students' misconceptions were analyzed again to determine the level of students' misconceptions after learning with the PBL model based on multiple representations. The categories used are based on Table 1, then presented to see the comparison before and after remediation.

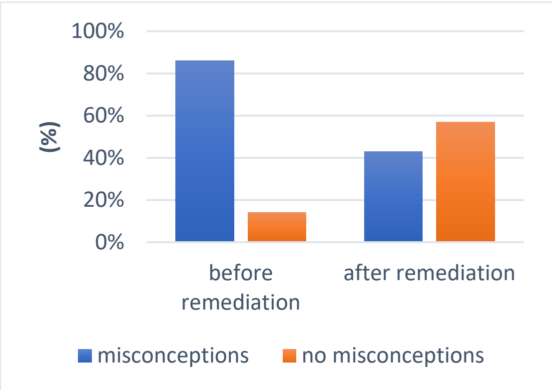

Figure 1. Percentage of Student Misconceptions

The reduction in misconceptions for each participant can be seen in Table 2, out of 30 students, 33% of students experienced a reduction in misconceptions in the high reduction category. However, on the other hand, 10% of students experienced an increase in misconceptions. The average percentage of reduction in students' misconceptions after remediation was 43% in the medium category.

Table 2. Percentage Reduction of Misconceptions for Each Student

Misconception Reduction Category	Percentage Reduction of Student Misconceptions
High	33%
Medium	30%
Low	27%
Misconceptions Increase	10%

2. Concepts that Occur as Misconceptions among Students

Analysis of students' misconceptions about thermochemical concepts is grouped into 9 concepts shown in Table 3.

Table 3. Percentage of Misconceptions on Thermochemical Concepts Before Remediation

No	Concepts	%
1	Systems and Surroundings	37.7
2	Exothermic and Endothermic	30
3	Standard enthalpy change of formation	35
4	Standard decomposition enthalpy change	18
5	Standard enthalpy change of combustion	17
6	Determination ΔH Based on Hess's law	35
7	Determination ΔH based on calorimeter data	13
8	Determination ΔH based on standard formation data	13
9	Determination ΔH based on binding energy data	17

3. Level of Misconceptions Reduction for Each Concept

The misconception reduction level profile was also analyzed for each remediated concept. Reducing misconceptions for each concept uses a formula adapted from the normalized gain formula developed by Hake. The reduction in thermochemical misconceptions can be seen in Table 4.

Based on the table, it can be seen that the highest level of misconception reduction after remediation is in the system and surroundings concept at 75.5% in the high category. Meanwhile, the lowest level of reduction was found in the exothermic and endothermic concepts at 15.3% in the low category. The average percentage of reduction in misconceptions for each concept after remediation is 44% in the medium category.

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Table 4. Percentage of Misconceptions on Thermochemical Concepts After Remediation

No	Concepts	Misconceptions	1st Mis Test (%)	2nd Mis Test (%)	Reduction (%)	Category
1	Systems and Surroundings	Identifies the container as a system	37.7	9	75.5	High
2	Exothermic and Endothermic	In an exothermic reaction, the temperature of the system will decrease because it releases heat into the surroundings	30	25.5	15.3	Low
3	Change in Standard Enthalpy of Formation	Formation of compounds from other compounds, and assuming that the word "generates energy" in the formation reaction has a positive value.	35	21.5	38.6	Medium
4	Determination of Enthalpy Changes Based on Hess's law	The number of reaction stages can affect the magnitude of the enthalpy change.	35	18.7	46.6	Medium
	Average misconception reduction for each concept				44%	

B. Discussion

1. System and Surrounding Reduction

The level of misconception in the system and surrounding concepts before remediation was carried out was 37.7%. There are three question items, namely 2, 8, and 14. Question items number 2, 8, and 14 are questions that reveal students' conceptual understanding of identifying systems and surroundings in chemical reactions.

Students experience misconceptions in identifying systems and surroundings. Students can provide the correct definition of the system and surroundings, where the system is everything whose changes are noticed, while the surroundings are everything outside the system, which limits the system and influences the system. However, students cannot identify the system and surroundings correctly. According to students, water, NaOH and test tubes are part of the system, while the surroundings are air and everything outside the system. Therefore, the majority of students experience false negative level misconceptions.

The system is the part of the universe that we want to focus on or pay attention to, while the surroundings include everything else in the universe. In this case, the system is defined as the reactants and products in a chemical reaction. The surroundings consist of the reaction vessel, the chamber, and anything other than the adhesive and product [19]. So what acts as a system is water and NaOH. Meanwhile, the surroundings are everything outside the system, which limits the system and influences the system, so that the container is included in the surroundings.

When interviews were conducted with ten students, they were able to define the system and surroundings well, but when asked questions regarding chemical reactions in a container, all students answered that the container was a system. The cause of this misconception is the mistake of educator who say "The bottle and everything in it is a system"

After remediation was carried out, students' misconceptions about the system and surrounding concepts were reduced by 75.5% in the high category. In item number 2, students' misconceptions are completely reduced by 100%. Question item number 8, students' misconceptions were also completely reduced by 100%. Meanwhile, item number 14 was reduced by 18%, 6 students experienced false-positive levels of misconceptions and two students experienced specific levels of misconceptions (Figure 2).

Students' conceptions also changed after remediation was carried out, which can be seen in Table 5. we can see that most of the changes in participants' conceptions turned into understanding the concept. This is because, in the learning process using the PBL model, students tend to find out and discuss what is meant by the system and surroundings, then relate it to what is around them. This is following the theory of the advantages of PBL in improving critical thinking skills when solving problems in groups.

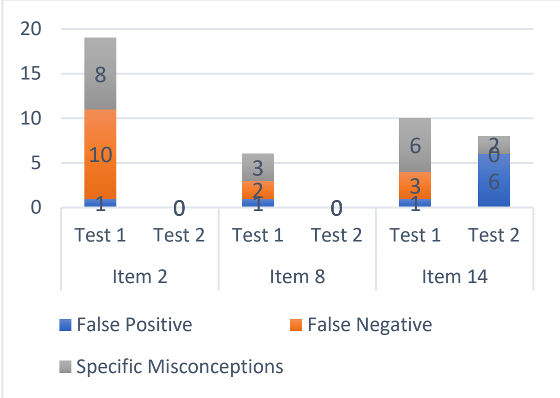

Figure 2. Reducing Student Misconceptions on System and Surroundings Concepts

Table 5. Changes in Students' Conceptions of System and Surroundings Concepts

items	**Changes in Students' Conceptions**		
	false positive	***False Negatives***	**Specific Misconceptions**
8	All students who experienced false positives changed to understand the concept after remediation	All students who experienced false negatives changed to understand the concept after remediation	All students who experienced Specific Misconceptions changed to understand the concept after remediation
2	All students who experienced false positive misconceptions changed to understand the concept after being corrected	8 students who experienced false negative misconceptions changed to understanding the concept, and two students changed their conception to not understanding the concept.	5 students who experienced specific misconceptions changed to understanding the concept, and three students changed their conception to not understanding the concept
14	All students who experienced false positives changed to understand the concept after remediation.	two students who experienced false negatives changed to understand the concept, and one student changed the concept to a false positive misconception.	three students who experienced specific misconceptions changed to understand the concept, two students changed their conceptions to false positives and one student maintained specific misconceptions.

2. Reduction of Exothermic and Endothermic Reactions

The level of misconception in the concept of exothermic and endothermic reactions before remediation was carried out was 30%, consisting of five question items, namely 1, 3, 4, 7, and 9 are questions that reveal students' conceptual understanding of identifying types of exothermic and endothermic reactions.

Students experience misconceptions in identifying exothermic and endothermic characteristics. Students can define exothermic and endothermic correctly, but if given examples of exothermic and endothermic reactions, students cannot give the correct answer in determining the characteristics of exothermic and endothermic. According to students, endothermic reactions increase the surroundings' temperature after the system is mixed, whereas exothermic reactions result in a decrease in the surroundings' temperature after the system is mixed. Students believe in these reasons, so students are categorized as having false-positive level misconceptions.

In endothermic reactions, heat must be supplied to the system by the surroundings, for the reaction to occur. Thus, heat energy is transferred from the surroundings to the system in an endothermic process [20]. So it can be concluded that in an exothermic reaction, the temperature of the surroundings will rise, and in an endothermic reaction the surrounding temperature will fall.

When the interview was conducted, most of the students were able to define and explain the meaning of exothermic and endothermic reactions with true, but students still have difficulty if they have been connected to something chemistry experiment. “sometimes reversed between exothermic and endothermic if brought to chemical experiments or examples in everyday life, when the temperature rises, and when the temperature drops, it sometimes reverses," said the student.

After remediation, students' misconceptions about the concepts of exothermic and endothermic were reduced by 15.3%. Apart from that, there has been a change in students' conceptions which can be seen in Table 6. Based on this table, it can be seen that most of the changes in participants' conceptions resulted in an understanding of the concept. This is because the learning process uses a PBL model accompanied by representation in animated videos, making it easier for students to understand chemical concepts. This is following research from Jonassen [14] that cognitive assistance will help students understand problems presented and help solve problems. Animated video cognitive aids illustrate the process of chemical reactions in everyday life. The animated video shows symbolically and submicroscopically how heat enters the system and how the system releases heat into the environment. The percentage of misconceptions in the concept of exothermic and endothermic before and after remediation can be seen in Figure 3.

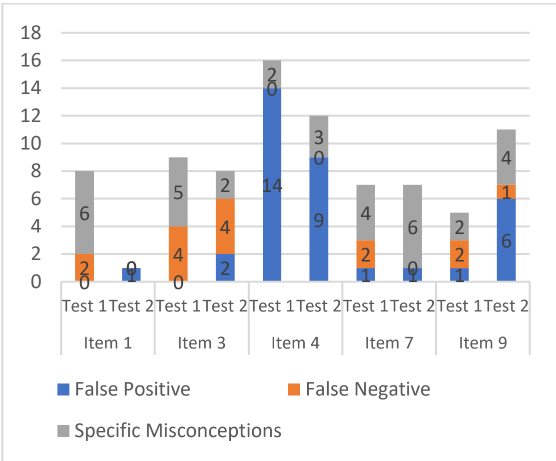

Table 6. Changes in Students' Conceptions of Exothermic and Endothermic Concepts

items	Changes in Students' Conceptions		
	false positive	***False Negatives***	**Specific Misconceptions**
1	No one experienced a false positive	All students who had false-positive misconceptions changed to understand the concept	All students who have specific misconceptions change to understand the concept
3	No one experienced a false positive	All students who had false-positive misconceptions changed to understand the concept	One student who experienced specific misconceptions maintained specific misconceptions, two students changed their conception to not understanding the concept and one student changed to understanding the concept.

items	Changes in Students' Conceptions		
	false positive	*False Negatives*	Specific Misconceptions
7	All students who had false-positive misconceptions changed to understand the concept	One student who experienced a false positive changed to understand the concept and one student changed the concept to a specific misconception	3 students who experienced specific misconceptions changed to understand the concept and one student continued to experience specific misconceptions
9	One student who experienced a false positive changed the concept to a false positive and one changed to understanding the concept	two students whose false positive misconceptions turned into specific misconceptions	two students whose specific misconceptions turned into not understanding the concept
4	6 students who experienced false positives changed to understanding the concept, three students changed their conception to not understanding the concept, three changed to false positives and two changed to specific misconceptions	No one experienced a false negative	One student who experienced a specific misconception turned into a false positive and one changed into not understanding the concept.

3. Change in Standard Enthalpy of Formation ($\Delta H_f°$)

The level of misconception in the concept of change in standard enthalpy of formation before remediation was carried out was 35%, consisting of two questions, namely 5 and 11 are questions that reveal students' conceptual understanding in defining standard enthalpy changes of formation.

Students experience misconceptions in defining changes in the enthalpy of formation. Students give reasons in the misconception test that the formation of standard H_3PO_4 acts as a product formed by other compounds. Giving wrong answers and wrong reasons, then being confident in the answers given, so that most students experience misconceptions at a specific level of misconception. Symbolized change in standard enthalpy of formation $\Delta H_f°$ is defined as the enthalpy change that accompanies the formation of one mole of a compound from its elements [19].

During the interview, students did not understand that the standard enthalpy change of formation is defined as the amount of energy required to form one mole of a compound from its elements, rather than being formed by other compounds.

After remediation was carried out, students' misconceptions regarding the concept of changes in standard enthalpy of formation were reduced by 38.6% in the medium category. Apart from that, there was also a change in students' conceptions (Table 7). In question item number 5, students' misconceptions increased, this was due to changes in students' conception levels from not understanding to misconceptions with a false positive rate. After remediation was carried out, students' understanding of item 5 increased. Question item number 11, there was an increase in students' understanding of concepts. Students still experience misconceptions because they are mistaken that the oxygen element that exists in nature is O_2 and not O, so four students gave the wrong answer but the reason is correct, therefore in question item number 11, the students experienced a false positive level misconception. The percentage of misconceptions in the concept of change in standard enthalpy of formation before and after remediation can be seen in Figure 4.

In the PBL model, students must be guided well, so that the discussions that occur are by actual concepts and there is no increase in misconceptions about certain items. In the learning process, students are given representations regarding the process of forming a molecule in everyday life. Representations are given through videos and teaching matters based on multiple representations.

This is also following research results from Jonassen [14], that providing cognitive assistance is very important to make it easier for students to understand abstract chemical concepts.

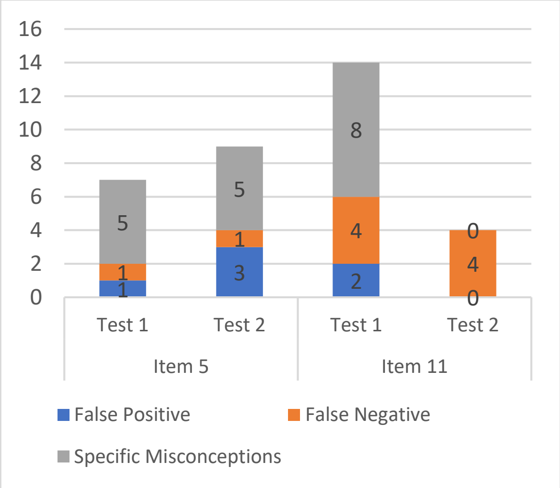

Figure 4. Reducing Student Misconceptions on $\Delta H_f°$ Concepts.

Table 7. Changes in Students' Conceptions on the Concept of Changes in Enthalpy of Formation of Standards.

items	**Changes in Students' Conceptions**		
	false positive	***False Negatives***	**Specific Misconceptions**
5	All students who experience false positives change their conception to understand the concept	All students who experienced a false negative changed their conception of understanding the concept	Two students who experienced specific misconceptions changed their concepts to understand the concept, one student remained with specific misconceptions, one changed to a false positive, and one did not understand the concept.
11	One student who experienced a false positive changed their conception to understanding the concept and one student changed their conception to not understanding the concept	Two students who experienced false negatives changed their conception of understanding the concept and two students changed their conception of not understanding the concept	5 students who experienced specific misconceptions changed their conceptions to understand the concept, one student changed their conception to a false negative and two changed to not understanding the concept.

4. Determination of Enthalpy Changes Based on Hess's Law

The final concept in the thermochemical matter that undergoes remediation is determining enthalpy changes based on Hess's law, with a level of misconception before remediation of 35%, consisting of three questions, namely 6, 13, and 15 questions that reveal students' conceptual understanding in completing and solving the determination of enthalpy changes based on Hess's law.

Students experience misconceptions about this concept because they assume that enthalpy changes are also influenced by the number of reaction stages. According to students on Hess's law, the more stages of a reaction that occur, the greater the enthalpy. Students are convinced of this reason, in the misconception test students are also unable to answer correctly so most students experience misconceptions at the specific level of misconceptions. Enthalpy is a state function, which is influenced by the change in enthalpy from the initial state to the final state, regardless of the path or stage of the reaction. This means that in moving from a certain group of reactants to a certain group of products the enthalpy change remains the same whether the reaction takes place in one stage or several stages [19].

When interviews were conducted with several students, they still did not understand the concept of Hess's law well. When asked questions related to the sound of Hess's law, the students were not able to answer correctly. Apart from that, students' calculation abilities are also an important indicator in the concept of determining enthalpy changes, according to educators, students' calculation abilities are still low.

After remediation, students' misconceptions regarding the concept of determining enthalpy based on Hess's law were reduced by 46.6% in the medium category. Apart from that, there is also a change in students' conceptions which can be seen in Table 8. In the PBL model based on multiple representations, students are given representations, both graphic and animated videos, through prepared teaching matters. Researchers also provide examples in everyday life related to Hess's law. By providing cognitive assistance based on multiple representations, students can easily understand the concept of Hess's law. This is following research results from Widarti [16], that to understand chemical concepts, the integrity of 3 levels of representation is needed. The percentage of misconceptions in determining enthalpy changes based on Hess's law before and after remediation can be seen in Figure 5.

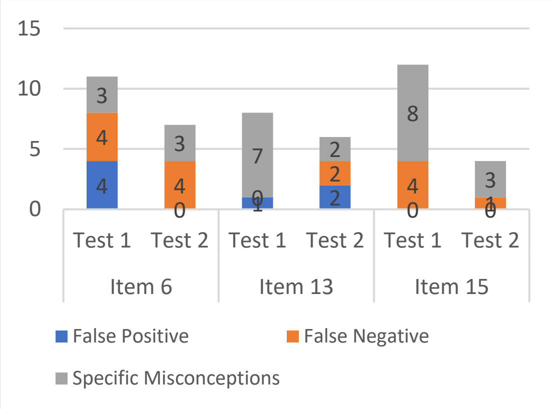

Figure 5. Reducing Student Misconceptions on ΔH Based on Hess's Law Concepts

Table 8. Changes in Students' Conceptions of the Concept of Determination ΔH Based on Hess's Law.

items	Changes in students' conceptions		
	false positive	***False Negatives***	**Specific Misconceptions**
13	All students who experienced false positive misconceptions changed to understand the concept	No one experienced a false negative	All students who experience specific misconceptions change their conceptions to understand the concept
6	One student who experienced a false positive changed their conception to understand the concept and three changed their conception to specific misconceptions	Two students who experienced false negatives changed their conceptions to understand the concept and two changed their conceptions to false negatives	One student who experienced specific misconceptions changed their conception to understand the concept, one changed their conception to a false negative and one changed to not understanding the concept.
15	No one experienced a false positive	All students who experience false negative misconceptions change their conceptions to understand the concept	5 students who experienced specific misconceptions changed their conceptions to understand the concept, two students maintained specific misconceptions, and one changed to not understanding the concept.

CONCLUSION

1. Students' misconceptions of thermochemical matter in the concepts of system and surroundings (37,7%), exotherm and endotherm (30%), standard enthalpy formation changes (35%), and determining enthalpy changes based on Hess's law (35%).
2. Thermochemical remediation through the problem-based learning model provides a reduction rate of 44% in the medium category, while the reduction percentage of students after remediation is 43% in the medium category.

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