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Chemistry Teachers' Perspectives to Enchancing Representational Competence in Learning Thermochemistry

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Abstract: Representational competence is very essential for students because it is associated with the students' ability to use, interpret, translate and integrate chemical representations to understand chemical concepts properly. In this case, implementation of the various representations utilization is required in learning Thermochemistry to improve students' representational competence to fully understand Thermochemistry. Therefore, this study aims to analyze teachers' perceptions towards the understanding and implementation of chemical representations in chemistry learning to improve students' representational competence in thermochemistry. This research is a descriptive quantitative research conducted using survey method that involved 30 chemistry teachers. The sample in this study was taken by purposive random sampling at public and private high schools in East Java. The data were collected through a questionnaire using google form application. According to the results of the study 63.3% of teachers still have difficulty in teaching students the concept of thermochemistry using submicroscopic representations. The majority of teachers only use symbolic representations, even though the other two representations are very important. Although 77% of teachers have understood chemical representations, in teaching and measuring concept understanding, teachers have not integrated chemical representations. This is due to their lack of self-awareness about the importance of using various representations in improving students' representational competence. Thus, training on representations is necessary in improving teachers' understanding on chemical representations. The findings of the study stated that teachers' understanding of representation and teachers' experience in participating in the trainings contributed to the effectiveness of the implementation of various chemical representations utilization to improve students' representational competence on the concept of thermochemistry.

Keywords: representational competence, chemical representation, and thermochemistry.

▪ INTRODUCTION

Chemistry is one of the natural sciences that studies the composition, structure of substances, chemical reactions, energy and energy conversion that accompany chemical reactions. Chemistry is one of the subjects that is difficult to comprehend because it has abstract, complex and multilevel concepts so that learning it requires gradual understanding.

Chemistry, specifically in the thermochemistry chapter, is a branch of thermodynamics that deals with heat in chemical and physical changes (Silberberg, 2013). Thermochemistry is one of the concepts in chemistry that is often considered difficult by teachers and students. The concepts in thermochemistry that are often viewed as challenging can be found in the material of energy and energy conversion accompanying chemical reactions, the difference between heat and temperature, identifying environmental and system differences in a chemical reaction and determining enthalpy changes following a chemical reaction (Wren & Jack, 2013). The difficulties encountered by students in thermochemistry can be caused by several factors, one of which is due to the characteristics of thermochemistry which is a concrete and requires

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mathematical calculation operations so that it involves abstract reasoning and complex understanding. The existence of such reasoning requires students to have conceptual and algorithmic understanding. Conceptual understanding is associated with the ability to understand the material taught in a way that is easy to understand, interpret and apply. Algorithmic understanding is related to calculation procedures in solving a problem. Memorizing formulas to solve problems in calculations and memorizing various facts in thermochemistry is important for long-term memory however, this does not guarantee that students can improve both understandings. Therefore, significant understanding is needed so that students are able to build thermochemistry concepts accordingly. Johnstone (1993) stated that a significant understanding can be improved with three chemical representations, namely macroscopic, submicroscopic, and symbolic (Chandrasegaran et al, 2007).

Macroscopic representation is a representative obtained through real observation of a phenomenon that can be seen directly and felt by the five senses such as changes in temperature, color, the presence of sediment in a solution and pH in a solution. Submicroscopic representation is a representation used to describe and explain the structure and entity of processes at the particle level such as atoms or molecules associated with the particle movements such as electrons, molecular atoms on macroscopic phenomenon. Understanding submicroscopic phenomena requires the ability of imagination and visualization that can be expressed in the form of diagrams, images, words, or two-dimensional or three-dimensional animations. Symbolic representation is a representation used to explain macroscopic and submicroscopic representations in the form of chemical symbols, chemical formulas, reaction equations or diagrams (Gilbert & Treagust, 2009).

The three representations are essential in learning thermochemistry material. For instance, in the event of heat transfer in a chemical reaction. In understanding the heat flow, students need a macroscopic representation. It also requires submicroscopic depiction which will then be written in symbolic form in the thermochemistry equations.

However, the majority of chemistry lessons in high school only use two representations in general, namely macroscopic and symbolic representations. Submicroscopic representation is rarely used in learning because it is considered difficult to understand (Gilbert & Treagust, 2009). In fact, a complete understanding of chemical concepts can be obtained, if students are able to use all three representations together properly (Gabel, 1998). This understanding is not only possible to use all three representations in understanding chemistry (Talanquer, 2011). However, in understanding the concept of chemistry as a whole also requires the ability, namely representational competence (Kozma & Russell, 2005).

Representational competence is the ability in using representations to study, communicate and solve problems in chemistry (Kozma & Russell, 2005). This ability consists of several aspects including the ability to interpret the meaning of chemical representations, the ability to translate between several chemical representations at various levels, the ability to use chemical representations to generate explanations, and the ability to connect chemical representations using concepts (Sim et al, 2014). The competence of chemical representation plays an important role in solving problems in chemistry and understanding chemical concepts (Hilton & Nicols, 2011). The learning process will be easier and more insightful if the teacher can integrate various chemical representations. If the teacher is able to apply various representations in learning process, then students will be trained to use various chemical representations in understanding chemical concepts. Students who are familiar with the use of chemical representations can improve their representational competence. These competencies can help students remember chemical concepts better (Tuysuz, 2011). Therefore, students need to improve representational competence in order to understand chemical concepts as a whole and can help solve problems in learning chemistry.

If students cannot understand the concept as a whole, it can lead to misconceptions. To minimize this, teachers need to integrate students' representation competencies so that students do not experience misconceptions. Apart from the importance of representational competence in the success of chemistry teaching and learning, it is necessary to conduct a study on the response of high school chemistry teachers to their understanding of chemical representation and the implementation of chemical representation in learning so as to improve students' representational competence on the concept of thermochemistry.

This study aims to further examine teachers' responses on the effectiveness of using various chemical representations in learning thermochemistry, teachers' understanding and experience in applying and attending training on various chemical representations. This study will also discuss the relationship among the factors that affect the effectiveness of chemical representation application in learning thermochemistry on teachers' understanding, training, and school type. This research is expected to provide insight into the importance of using various chemical representations to improve students' representational competence in understanding the concept of thermochemistry.

▪ METHOD

Participants

The population in this study are public and private high school chemistry teachers in East Java. The studied sample are 30 high school chemistry teachers who represent public and private high schools in East Java. The sampling technique in this study was conducted by purposive random sampling. Purposive random sampling is a technique to select respondents based on certain considerations (Creswell, 2012). The samples selected in this study are high school chemistry teachers in East Java.

Research Design and Procedures

This research is a descriptive study that also use a quantitative approach. The method used in this research is the survey method, which is a technique used to collect data in the form of questions given to respondents (Fraenkel et al, 2012). This research procedure was implemented through several steps as presented in Figure 1.

The stages in this study begin with formulating the problem by reviewing the literature and identifying issues that exist in chemistry teaching and learning. Based on the formulation of the problem that has been determined, the research methods, research subjects, data collection techniques, and the preparation of non-test instruments will be selected. Instruments that have been validated can be distributed to respondents via google form.

The data that has been collected is then analyzed both qualitatively and quantitatively. Qualitative analysis is used to identify the perception of chemistry teachers, while quantitative analysis is used to determine the general description, correlation, and differences between variables. Quantitative analysis in this study includes

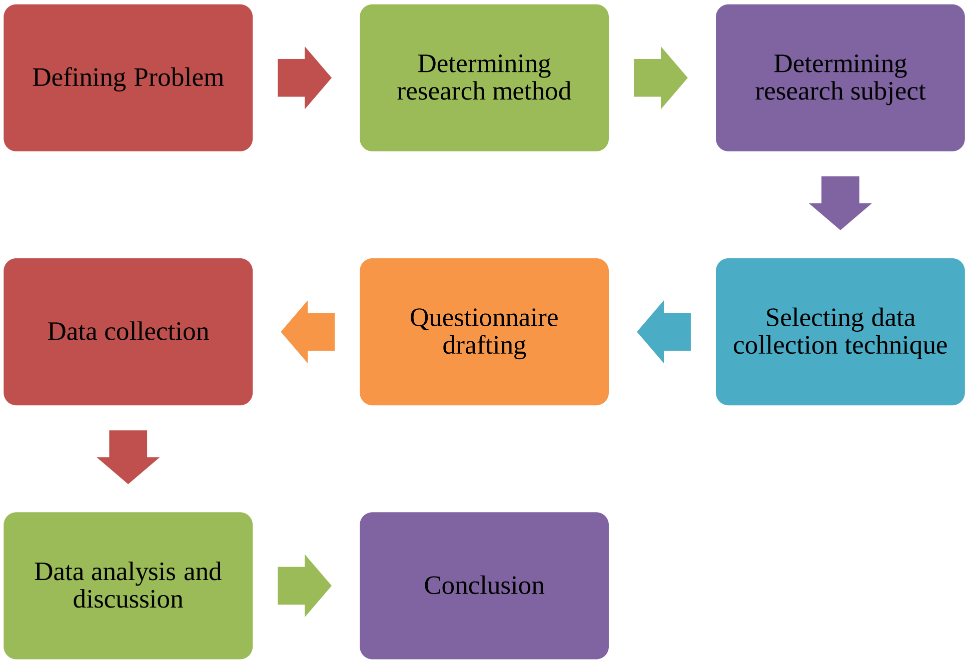

Figure 1. Research Procedure

descriptive analysis, correlation test, multiple regression test and independent sample t-test. The data that has been analyzed is reviewed and conclusions are drawn.

Instruments

The data collection instrument used in this research is a non-test instrument in the form of a questionnaire. The questionnaire used in this study consists of two sections, namely section A and section B. Section A, in the form of questions with a Likert scale of 1-5 to measure teachers' perceptions on the indicators studied. While Section B, in the form of open-ended questions to obtain qualitative information from respondents. The questionnaire in this study was prepared based on three main indicators, each of which consisted of several questions as shown in Table 1.

Table 1. The key indicators of the questionnaire and the questions contained within each item

No	Key Indicators	Questions contained within each item	
		Section A	**Section B**
1	Teachers' perceptions of students' understanding and difficulties in the concept of thermochemistry	1. Teachers' perceptions on the extent to which students are familiar with the concept of thermochemistry	1. Teachers' perceptions of sub-concepts that are often considered difficult by students in the concept of thermochemistry
		2. Teachers' perception of students' level of understanding on the thermochemistry concept	

		3. Teachers' experience in integrating thermochemistry concepts in classroom chemistry learning	
2	Comprehension and application of chemical representation in learning thermochemistry according to perception of chemistry teachers	4. To what extent do teachers recognize chemical representations	2. Teachers' comprehension of chemical representations
		5. Teachers' experience in integrating chemical representations for learning thermochemistry chemistry	3. Types of chemical representations that are considered difficult to use in learning thermochemistry
		6. Teachers' experience in integrating symbolic representation in learning thermochemistry	4. Teachers' perceptions of which visual representations are most effective in helping students to understand chemistry concepts
		7. Teachers' perceptions about the extent to which chemical representations can help improve students' understanding of the concept of thermochemistry	
		8. Teachers' experience in training programs on chemical representation	
3	Teachers' perceptions towards the use of various representations in learning thermochemistry to improve students' representational competence	9. Teachers' self- confidence in integrating various representations for learning thermochemistry	5. Teachers' perceptions towards aspects of representational competence that are often considered difficult by students in understanding the thermochemistry concept.
		10. Teachers' perceptions on the effectiveness of using representations in learning thermochemistry	

The questionnaire that has been prepared is validated by two validators. The result of contents validation for the non-test instrument is 4.6 which indicates that the instrument is valid, with the result of the instrument reliability test of 0.8 which indicates that the instrument is reliable and there is agreement between the two validators.

The validated questionnaire can be used to collect data which was carried out from July 26, 2024 to August 11, 2024. The data collected was then analyzed. Data analysis on section B is qualitatively analyzed using qualitative content analysis to discuss each key indicator. Meanwhile, quantitative data obtained from section A will be subjected to descriptive analysis and several tests. Descriptive analysis in section A is needed to support the discussion on the key indicators, that is by calculating the average indicators contained in several question items. The data that has been tested for normality is then carried out several tests including the spearman correlation test, multiple regression, and independent sample t-test. Spearman correlation test was used to determine the relationship between teachers' understanding of chemical representation and the effectiveness of representation implementation in learning thermochemistry. Multiple regression test was used to determine the factors that influence the effectiveness of representation implementation in learning thermochemistry such as teachers' understanding of representational competence and Teachers' Practice for Molecular Modeling. Independent sample t-test was used to determine the difference in the effectiveness of representation implementation in learning thermochemistry between private and public teachers.

The correlation between variables can be seen through 2-tailed significance with a significance level of 0.05. While the correlation can be determined through the correlation (r) which can be interpreted based on Creswell (2012) presented in Table 2.

Table 2. Correlation criteria

Grade	Criteria
0.00 – 0.19	Very weak
0.20 – 0.39	Weak
0.40 – 0.59	Average
0.60 – 0.79	Strong
0.80 – 1.00	Very Strong

▪ RESULT AND DISSCUSSION

The questionnaire given to high school chemistry teachers was used to find out information about teachers' perceptions regarding their students' understanding of thermochemistry material through classroom learning assessments, teachers' understanding of chemical representations, and teachers' perceptions of the implementation of various chemical representations in thermochemistry material according to the results of the questionnaire

Teachers' Perception on Students' Understanding of Thermochemistry Subject

The results of the research data stated that the perceptions of some teachers toward their students' understanding at school in relation to the concept of thermochemistry were 13.3% (very good), 63.3% (good) and 23.3% (quite good).

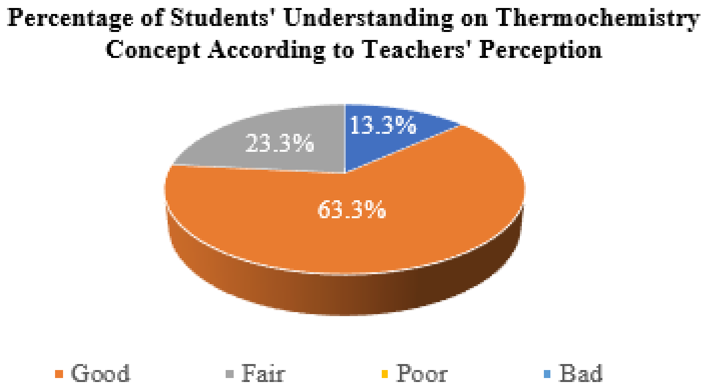

Figure 2. Percentage of students' understanding on thermochemistry concept according to teachers' perception

Based on the questionnaire results shown in Figure 2, it shows that students' concept understanding according to the perceptions of chemistry teachers on the concept of thermochemistry as a whole in East Java is quite good. Although students' understanding is in the good category, however, based on statements from several teachers in Table 3. shows that most students from their schools have difficulty in determining enthalpy changes based on calorimeters, Hess' law, and bond energy.

Table 3. Perceptions of chemistry teachers in East Java about subconcepts within thermochemistry that are often considered difficult by students

Teacher	Sub-concept	Teacher	Sub-concept
G1	enthalpy calculation	G16	Enthalpy change determination based on Hess' Law
G2	Exothermic and endothermic reactions	G17	Calorimetry
G3	Determination of enthalpy change using calorimeter	G18	Determination of enthalpy change based on bond energy
G4	enthalpy calculation	G19	Determination of enthalpy change rate
G5	Enthalpy change determination based on Hess' Law	G20	Standard enthalpy change
G6	Enthalpy of standard formation, Determination of enthalpy change based on Hess's Law and calorimetric calculation	G21	Enthalpy calculation
G7	Determination and Measurement of Enthalpy Change	G22	Measurement of enthalpy change using a calorimeter
G8	Applications of thermochemistry in daily life	G23	Graph/diagram reading
G9	Calculations in thermochemistry	G24	Determination of enthalpy change using a calorimeter bomb
G10	Enthalpy calculation	G25	Determination of enthalpy changes in several reactions
G11	Calculating the enthalpy	G26	Enthalpy calculation
G12	Chemical elements	G27	Laws in thermochemistry
G13	Calculating the enthalpy value of reaction	G28	Determination of enthalpy change based on Hess' Law
G14	Determination of enthalpy change using a calorimeter	G29	Determination of enthalpy change based on Hess' Law
G15	Determination of enthalpy change based on Hess' Law	G30	Thermochemistry principles when associated with enthalpy and Hess' law

After further investigation, the difficulty according to some teachers, is caused by the fact that most students cannot solve the problem of determining enthalpy changes based on Hess' law. For instance, in problems that require students to determine enthalpy changes from energy level diagrams or through reactions that are described submicroscopically. In addition, when students are given problems to determine enthalpy changes based on bond energy, students often complain because of the difficulty in describing chemical structures to determine average energy.

Another teacher stated that some students had difficulty in differentiating exotherm and endotherm reactions (G2), application of thermochemistry in daily life (G8) and reading graphs in diagrams (G23). Based on the teacher's perception, the difficulty is because most students only memorize the facts alone, so that many students have forgotten when they are assessed.

Teachers' Understanding of Chemical Representations

One of the difficulties experienced by students in learning thermochemistry is due to the abstract nature of the concept. Abstract concepts can be understood by students using chemical representations. The use of various representations to explain either multiple representations or single representations becomes one of the tools to assist students in developing their scientific knowledge. The use of different representations with different learning styles makes the concepts in thermochemistry easier to understand and enjoyable for students because each representation mode has different communication meanings (Ainsworth, 2008).

In practice, the majority of high school chemistry teachers in Indonesia, particularly in East Java, are familiar with chemical representations. However, there was a misalignment when they were asked to define the term representation (n=1). In addition, there were some teachers who did not understand and did not answer the question related to the term chemical representation (n=7). The other 77% of teachers already understood chemical representation, but some of them still had difficulty in defining the term chemical representation as shown in Table 4. This indicates that not all the high school chemistry teachers in East Java are well-informed about chemical representations.

Table 4. High school chemistry teachers' understanding on chemical representation

Teacher	Teachers' understanding of chemical representations	Teacher	Teachers' understanding of chemical representations
G1	I don't quite understand	G16	Depiction of a phenomenon
G2	Chemical representation is a way of expressing abstract phenomenon, concepts, ideas and mechanisms in macroscopic, microscopic, and submicroscopic ways.	G17	Practical presentation
G3	Make use of surrounding phenomenon to help illustrate chemical concepts to students. Either through discussion or direct practice	G18	Methods for expressing concepts and processes in chemistry

G4	-	G19	-
G5	Provide real-life examples of chemistry concepts	G20	Expressing chemical phenomenon, ideas, and mechanisms
G6	A method for describing and conveying information about elements, compounds, and chemical reactions using symbols, formulas, and equations	G21	Expressing chemical phenomenon, ideas, and mechanisms
G7	Chemical representations is a way to express phenomenon, concepts, ideas, and mechanism processes	G22	The delivery of the material is associated with daily life events
G8	Chemical elements	G23	Scientific manner
G9	Part of the chemistry learning field	G24	A way to explain or present a phenomenon, an abstract chemical concept, and the process of a chemical reaction
G10	A way of expressing a phenomenon, abstract concept, or idea	G25	Tetrahedral representation. Which describes a material in 4 kinds of forms (macro, micro, symbolic, and its application)
G11	Macroscopic, submicroscopic and symbolic understanding	G26	-
G12	The reactions	G27	-
G13	Vague understanding	G28	A depiction of a concept in chemistry
G14	To provide meaning to the material being explained at the macroscopic level, submicroscopic level, and symbolic level	G29	to help illustrate the concept of chemistry
G15	Not too familiar with	G30	Chemical representation is a method to make it easier for students to understand chemistry

However, if teachers are able to understand and apply chemical representations in their teaching and learning, it can help students understand the concept of thermochemistry. For example, teachers can create an animation that is depicted submicroscopically to explain water heated in a closed container. If the animation is integrated in classroom learning, it can help develop students' mental behavioral models. Based on the animation, students can learn that heated water can increase the kinetic energy of water molecules. In addition, it can also cause particle movement, due to the heat energy absorbed by the system in the environment and this process is classified as an endothermic process.

Based on this example, if teachers are able to understand well, then teachers can apply their understanding of representation in teaching and learning. Integrated chemical representations in learning process may improve students' understanding (Gilbert & Treagust, 2009). Teachers can improve students' understanding completely by providing single and multirepresentation-based learning modules to improve students' competence in understanding thermochemistry by using chemical representations.

Teachers' Perception towards the Use of Various Chemical Representations in Thermochemistry Learning

Upon further research on teachers' perceptions of the extent to which the use of various chemical representations can help improve students' understanding about the concept of thermochemistry, questionnaire data in Figure 3 shows that 53.3% of teachers consider that the use of various chemical representations is very helpful for students in understanding the concept of thermochemistry, 36.7% agreed that it is helpful, 6.7% goes with fairly helpful and 3.3% consider the use of various representations to be less helpful in learning thermochemistry.

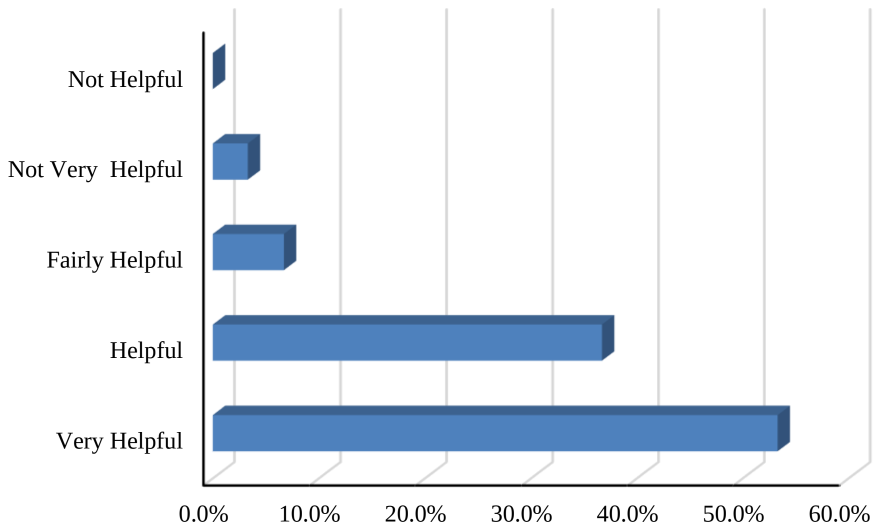

Figure 3. Teachers' perceptions on the use of various representations in learning thermochemistry

According to the derived percentage, some teachers still consider that the use of various representations in learning thermochemistry is still less effective. Whereas, the use of various representations in learning thermochemistry can provide support for students in achieving significant learning and is a good tool in developing their knowledge (Gilbert & Treagust, 2009). This shows that some high school chemistry teachers in East Java do not fully realize that the use of various chemical representations in chemistry learning is very essential for students.

However, after explaining the importance of using various chemical representations, they came to realize that teaching chemistry requires the use of various chemical representations. Submicroscopic representation is one of the reasons why teachers have difficulty to integrate various representations in the concept of thermochemistry. and also become a challenge for teachers in teaching the concept of thermochemistry to their students. This is shown in the questionnaire data which states that 63.3% of teachers have difficulty in making students understand the submicroscopic representation. While symbolic representation amounted to 23.3% and macroscopic representation amounted to 13.3% as presented in Figure 3.

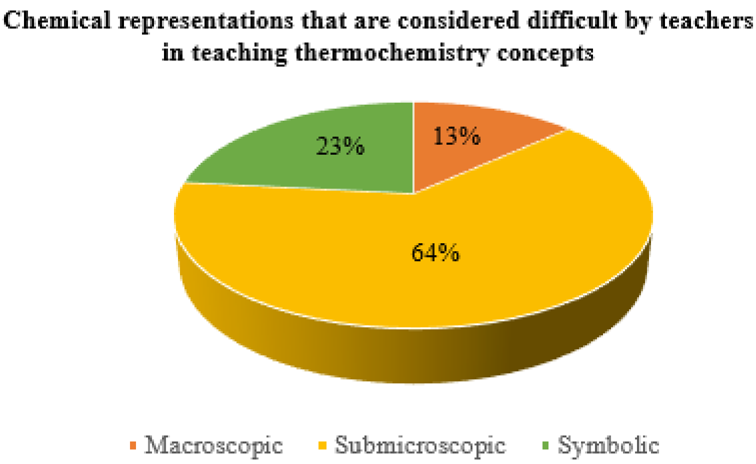

Figure 4. Chemical representations that are considered difficult by teachers in teaching thermochemistry concepts

Based on Figure 4. it indicates that in learning chemistry, particularly on thermochemistry subject matter, high school chemistry teachers in East Java find it much easier to integrate two representations, that are macroscopic and symbolic. While submicroscopic representation becomes one of the representations that are considered difficult by teachers in teaching their students on the concept of thermochemistry. In line with research conducted by Gilbert & Treagust (2009) which stated that submicroscopic representation is the most difficult representation to understand among the other three representations so that most students only use macroscopic and submicroscopic representations.

Submicroscopic representation is a representation that requires imagination and visualization as it is associated with chemical models, so that in providing submicroscopic images, students must be able to visualize structures and processes at the molecular level. However, the use of chemical models in thermochemistry materials is often not correlated with macroscopic representations, so that chemical models are only seen as symbolizations that are merely interpreted in a mathematical context (Chittleborough & Treagust, 2007).

Submicroscopic representation is one of the important representations because it is used as an important intellectual basis for explaining chemistry. But submicroscopic representation also becomes a weakness for teachers and students in understanding it in chemistry learning. This shortcoming causes submicroscopic representations to be often ignored compared to macroscopic and symbolic representations (Gilbert & Treagust, 2009).

The use of various representations either singular or multiple representations is needed by students in understanding the concept of thermochemistry entirely. Based on the questionnaire data presented in Figure 5. shows that 46.7% of teachers consider that the most effective representation method used in teaching thermochemistry among students is using the energy level diagram.

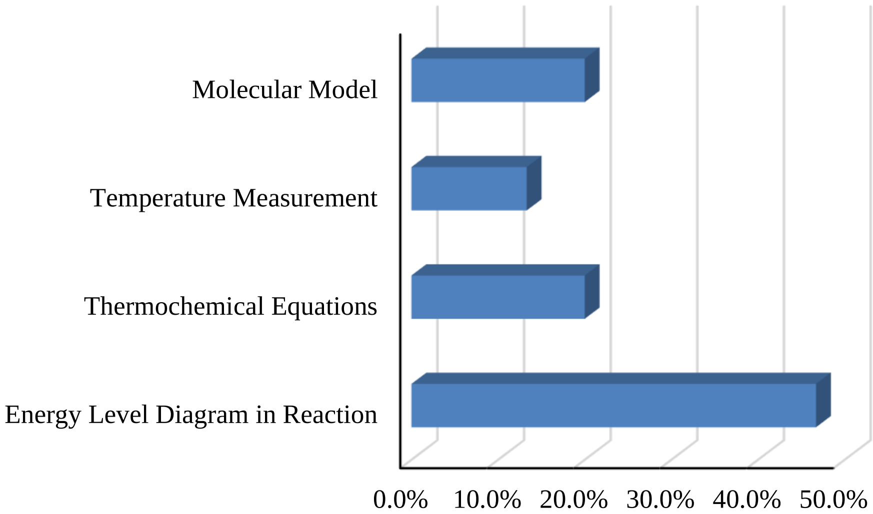

Figure 5. The mode of representation that is considered effective by chemistry teachers in teaching thermochemistry concepts to students

This means that in the teaching of students, symbolic representations manifested in the form of energy level diagrams are generally more effective than using macroscopic and submicroscopic levels of representation. Whereas, energy level diagram is one of the concepts that are difficult to understand by the majority of students. The difficulty can be caused by the lack of students' ability to use and correlate the three representations on the concept of thermochemistry.

The concept of thermochemistry cannot be understood with merely one representation, because the three representations are interconnected. If students are incapable of using the three levels of chemical representation, it can cause students to have difficulty in solving problems on the concept of thermochemistry (Chandrasegaran et al, 2007; Chittleborough & Treagust, 2007). Solving problems in thermochemistry concepts will be easier if students are able to correlate among the three chemical representations.

Understanding thermochemistry concepts using various representations requires several skills. According to Sim et al (2014), these skills consist of several aspects of ability, including the ability to interpret representations, the capacity to translate between representations either at the same level or at different levels, the capability to use representations to generate explanations, and the skill to correlate representations with the concept. Some aspects of these abilities can be used by students to improve their representational competence in understanding the concept of thermochemistry as a whole.

The research results presented in Figure 6 shows that 40% of teachers stated that the aspect of the ability to make a correlation between representations and thermochemistry concepts is the aspect of ability with the highest level of difficulty.

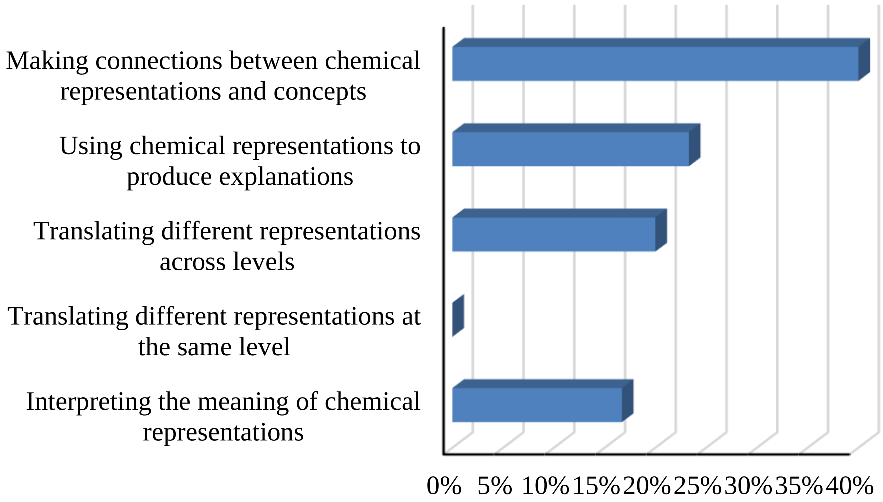

Figure 6. Students' skills in representational competence in integrating the use of various representations for chemistry learning in the classroom

Based on the research data in Figure 6, it shows that students' representational competence is still poor. Representational competence of students can be improved if students are frequently given questions that are integrated with several aspects of representational competence skills. These questions will help students in interpreting, translating, using, and correlating representations with chemical concepts (Gkitzia et al, 2019).

However, the data results show that only a few teachers measure students' understanding using instruments that are integrated with aspects of ability in representational competence. The majority of teachers in measuring the understanding of thermochemistry concepts use only cognitive tests, summative tests, and practice exercises that are more dominantly applied to test students' understanding in the process of memorizing only. Whereas, exercise questions and cognitive test are not sufficient to measure concept understanding as a whole and develop students' representational competence. After further research, it turns out that the majority of teachers still do not make efforts to develop students' representational competence. Only a small number of teachers are trying to improve students' representational competence.

In fact, improving representational competence is very important for students because it affects how students can solve problems in chemical concepts. Students must be given special emphasis in reading and interpreting chemical representations, in order to solve problems in chemistry. Teachers as educators in designing learning activities, providing exercise questions, and making teaching modules need to consider aspects of representational competence (Gkitzia, 2019).

Based on this analysis, Teachers' Practice for Molecular Modeling is highly required. Training that can be attended by teachers such as basic training on chemical representations that introduce chemical symbols and translate between representations and; training on making chemical representations by utilizing technology such as chemdraw, KingDraw, chemSketch, or other applications. The training can provide information on how to read representations, how to apply various chemical representations of chemistry learning, and can determine how to integrate various representations in teaching materials or learning media.

The numerous benefits of Teachers' Practice for Molecular Modeling may help teachers understand that the use of various representations is important in learning chemistry. In addition, this training can be useful for teachers to improve their understanding of representations and can be implemented to assist students in integrating the three chemical representations effectively to solve chemical problems. If students are able to utilize various representations and correlate them then students can overcome their learning difficulties. Students in this case can also see a better correlation between the various representations.

Factors Influencing the Effective Implementation of Chemical Representation in Thermochemistry in Thermochemistry Learning: Teacher Understanding, Training, and School Context

The correlation between teachers' understanding of chemical representations and the effective use of representations in learning thermochemistry can be seen through the correlation test.

Table 5. Results of correlation test

Correlations				
			Teacher's Understanding (Likert Score 1-5)	**Implementation Effectiveness (Likert Score 1-5)**
Spearman's rho	Teacher's Understanding (Likert Score 1-5)	Correlation Coefficient	1.000	.504**
		Sig. (2-tailed)	.	.005
		N	30	30
	Effectiveness (Likert Score 1-5)	Correlation Coefficient	.504**	1.000
		Sig. (2-tailed)	.005	.
		N	30	30

According to the results of the Spearman's rho correlation coefficient presented in Table 5. a value of 0.501 was obtained with a sig value. 2-tailed 0.0005<0.05. The significance shows that there is a significant positive correlation between teachers' understanding of chemical representation and the effectiveness of representation implementation in learning thermochemistry. This means that the higher the teacher's understanding of thermochemistry, the more effectively various representations are integrated into thermochemistry learning in the classroom. In other words, the more proficient of teachers' understanding on chemical representations, the better the effectiveness of using various representations in learning.

Effect size in this test is based on the Correlation Coefficient (r) value of Spearman's rho. Based on Table 5, the r value is 0.501 or 0.501>0.5, which indicates that there is a strong correlation between the effectiveness of using various chemical representations on teachers' understanding of chemical representations.

Meanwhile, the relationship between the effectiveness of the use of representations in learning thermochemistry on teachers' understanding and Teachers' Practice for Molecular Modeling can be found through the spearman test and multiple regression.

Table 6. Results of multiple regression test

Model Summary				
Model	**R**	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**
1	.539[a]	.290	.238	.420

Predictors: (Constant), Teachers' Practice for Moleculer Modelling (Dummy: 1= Pernah, 0=Belum), Teachers' Understanding (Skor Likert 1-5)

The test results presented in Table. 6 obtained an R value of 0.539 with a sig value. (p-value) = 0.010 <0.05 which states that the strength of the correlation between the three variables is moderate. This means that teachers' understanding of chemical representations and Teachers' Practice for Molecular Modeling contribute to the effectiveness of using various representations in learning thermochemistry.

Teachers' Practice for Molecular Modeling is very important for teachers, because by attending the training, teachers will have an understanding of how teachers use and utilize various representations effectively in chemistry learning. In addition, the training can also provide provisions for teachers to have skills in using single and multiple representations. Teachers will also be provided with inputs on how to integrate various representations in learning thermochemistry either in making teaching modules, assessments, exam questions or learning media.

Effect size in this regression analysis is interpreted through R2. The R2 value is 0.290 which indicates that teachers' experience in attending training and teachers' understanding of chemical representations have a large effect on the effectiveness of using various chemical representations in learning thermochemistry.

The difference in the effectiveness of the use of representation in learning thermochemistry both in public and private school teachers can be tested using independent sample t-test. According to the results of the independent sample t-test conducted to compare the average effectiveness of the use of representations in public and private school teachers is presented in Figure 7.

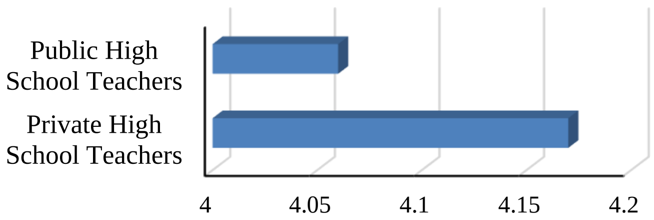

Figure 7. Average effectiveness of using multiple representations in learning thermochemistry among public and private school teachers

Based on the diagram presented in Figure 7. shows that the average effectiveness of the use of representation in learning chemistry between private and public high school teachers is not significantly different. The data is explained in the results of hypothesis testing presented in the following table.

Table 7. Results of independent sample t-test

Independent Samples Test						
	Levene's Test for Equality of Variances		**t-test for Equality of Means**			
					Significance	
	F	**Sig.**	**t**	**Df**	**One-Sided p**	**Two-Sided p**
Effectiveness	.071	.792	-.614	28	.272	.544

According to Table 7. sig. 2-tailed= 0.544> 0.05 indicating that there is no significant difference between the average effectiveness of public and private school teachers. Although it can be seen that the average effectiveness of using representations in private teachers is higher, there is not enough evidence that teachers from private and public schools are significantly different in their teaching effectiveness on thermochemistry using various chemical representations.

Table 8. Independent samples effect sizes

Independent Samples Effect Sizes					
				95% Confidence Interval	
		Standardizer[a]	**Point Estimate**	**Lower**	**Upper**
Effectiveness	Hedges' correction	.499	-.222	-.934	.493

Effect size for the average difference test on private and public chemistry teachers can be determined using Hedges' Correction. Then, based on Table 8, a value of -0.222 is obtained which indicates that the effective use of representation in private and public high school teachers has a negative effect. The first group has an average effective use of representation in public high school teachers is lower than private high school teachers. However, because the resulting value is very small <0.5, so the effect is very minor and not significant. The difference in means could be possible due to other factors, for example, private school teachers may have longer teaching experience than public school teachers. The difference in the means may also be a result of random variation in the data.

Given the findings, it shows that in improving students' representational competence on the concept of thermochemistry, teachers need to have an understanding of chemical representations. Teachers' understanding of representation can be improved by way of Teachers' Practice for Molecular Modeling. If teachers have understood various chemical representations and how chemical representations are applied in teaching and learning, then teachers can implement them in classroom learning. The implementation of various representations in learning thermochemistry will not only contribute to improving individual student competencies, but also contribute to the development of a more integrated curriculum.

Although the majority of teachers often use symbolic representations in learning thermochemistry, integrating macroscopic and submicroscopic representations is also essential (Chi, 2018). All three representations may improve students' representational competence in interpreting, translating or correlating various chemical representations with thermochemistry concepts and may strengthen students' understanding of chemical concepts.

This is in line with the research conducted by Popova & Jones (2021) which states that low representational competence is due to the fact that many teachers do not understand chemical representations so they do not integrate chemical representations in their classroom activities. However, at the same time, teachers realize that most teaching and assessment requires competence. Teachers in the study also reported their self-awareness of the lack of understanding of chemical representations. Despite the importance of using various chemical representations, teachers need to integrate various representations to improve students' representational competence.

▪ CONCLUSION

According to the research data, it can be concluded that 63.3% of teachers who are still having difficulty in making students understand the concept of thermochemistry by using submicroscopic representations. The other 36.6% had difficulty understanding the concept of Thermochemistry using symbolic and macroscopic representations. The difficulty is caused by the fact that in learning thermochemistry, most teachers only use symbolic representations. Although 77% of teachers understand the chemical representation, but not all teachers integrate various chemical representations in learning thermochemistry. Even in measuring their students' concept understanding, teachers only use cognitive questions, exercise questions and summative questions, which are more dominant in testing students' memorizing process. Whereas, questions that involve aspects of representation skills can determine students' concept understanding as a whole and help practice students' representation competencies. Consequently, students can only memorize abstract representations without knowing the concept in its entirety. In addition, the majority of teachers still have not tried to develop students' representational competence in thermochemistry material. Based on the results of this study, teachers are advised to follow the Practice for Molecular Modeling, in order to realize and provide information related to the importance of implementing various representations in chemistry learning which is useful for improving students' representational competence to gain a complete understanding of the concept. According to the findings, teachers' understanding and Teachers' Practice for Molecular Modelling contribute to improving the effectiveness of the use of various representations in learning Thermochemistry. By increasing the effectiveness of using various representations in chemistry learning, therefore the learning experience and representational competence in students will also increase.

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