Thermochemistry multiple representation analysis for developing intertextual learning strategy based on predict observe explain (POE)

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Thermochemistry multiple representation analysis for developing intertextual learning strategy based on predict observe explain (POE)

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Abstract. This article was written to describe the results of multiple representation analysis of concepts related to thermochemistry topic. The study was set under a qualitative method. It was found from the analysis of five General Chemistry textbooks that thermochemistry consists of three major concepts which include exothermic reaction, endothermic reaction, and enthalpy change. In macroscopic level, exothermic reaction was presented by several phenomena such as Ca(OH)₂ production. Meanwhile, endothermic reaction was presented by Ba(OH)₂·8H₂O and NH₄Cl reaction. In the sub microscopic level, all textbooks explained the concept of exothermic and endothermic reaction by using descriptive approach showing that reaction happened and followed by heat change. In addition, in symbolic level, the explanation was enriched by the use of chemical reactions equations, diagrams of energy level and the visualization of the system in releasing or receiving the heat. The macroscopic representation for concept of enthalpy change was presented as an experiment using calorimeter which then described by sub microscopic representation that the energy released is equal to the energy system accepted by environment. Last, in symbolic level, the explanation was enriched by the use of formula to calculate the enthalpy change. This finding was used for developing intertextual learning strategy based on POE.

1. Introduction
Thermochemistry is the application of thermodynamics to chemistry, the branch of chemistry that studies the interrelations between heat with chemical reactions or with physical changes. Thermochemistry is one of the subjects that are considered difficult, either by the students as well as college students. This article aims to test theoretically any misconceptions that occur with thermochemical concepts using descriptive methods. Thermochemistry is one of the subjects considered difficult by both students and college students. This is reflected in the study of the misconceptions that have been done by [1] on energy in chemical reactions; on calorimetry [2]; on the fundamental principles of thermochemistry [3]. Moreover, [4] expresses that thermochemistry is a topic which is not easy to understand because it is abstract. [5] also states that the level of conceptual understanding in thermodynamic concepts is very low. In general, thermochemistry is a difficult subject to understand. To understand the concepts of intact and comprehensive intertextual strategy is required.

Intertextual itself is a strategy that is used to connect between the text with the text one another. The conduct of learning intertextual learning is done by way of reconciling between the three levels of the
chemical, the representation of everyday life experience and knowledge has been previously owned [6]. On lessons of chemistry, there are three levels or levels that must be understood, namely the macroscopic level, submicroscopic level and symbolic level. Forming the cluster concept map is closed, such as figure 1.

![Figure 1. The chemistry triangle [7].](image)

To understand chemical phenomena students must understand the science and use scientific representation. Generally, students are having difficulty connecting the macroscopic and symbolic knowledge with knowledge of submicroscopic, so it will arise a lot of misconception when students convert knowledge to as low as submicroscopic [8]. Reinforced by those described by [9], of the three chemical representations, student misconceptions most often arise at the submicroscopic, the third of such chemical representation, the misconception of students most often appear on the level of submicroscopic. And in line with it also stated that, in fact, many students do not understand and do not use the third level representation in explaining a phenomenon [10].

The macroscopic level representation is a representation obtained by observation either directly or indirectly against a phenomenon which can be apprehended by the senses (sensory level) [11]. These observations can be retrieved through everyday experiences, simulation/demonstration or experiments in the laboratory, for example, change of temperature & color. Symbolic representation i.e. chemical representation obtained qualitatively or quantitatively, by the used of chemical formulas, diagrams, drawings, stoichiometry, chemical equation and mathematical calculations. For example, a molecular formula of water is H$_2$O. whereas the submicroscopic representation is a representation of chemistry that explained as to how and why the reaction of the macroscopic level it may occur at the level of the particles (atoms/molecules). Therefore, in this study, a preliminary study was undertaken by analyzing textbooks general chemistry for discovering the third level representation of chemistry. This is done as the initial stages of research entitled intertextual based strategies predict observe explain (POE) on the thermochemistry to improve the conceptual understanding and science process skills pre-service chemistry teachers.

2. Method
The research method is the way use by researchers to collect research data [12]. This research was set as qualitative method with document analysis techniques or documentation method. This method is the main method in data collection method used is content analysis. Through a sample of five textbooks of general chemistry, as indicated in following table 1.

| Textbooks | Title                      | Author                | Year |
|-----------|----------------------------|-----------------------|------|
| Textbooks 1 | The Foundation of Chemistry | Whitten, Davis & Pack [13] | 1998 |
| Textbooks 2 | The Essential Concept       | Chang & Overby [14]   | 2003 |
| Textbooks 3 | Principles of General Chemistry | Sibelberg [15]     | 2007 |
Tabel 1. Cont.

| Textbooks 4 | Principles of Modern Chemistry | Oxtoby, Gillis, Nachtrieb [16] | 2008 |
|-------------|--------------------------------|-------------------------------|------|
| Textbooks 5 | Principles and Modern Application | Petruci, Harwood dan Hering [17] | 2011 |

With the research stages:
1. Misconception analysis that occurs on thermochemical topic.
2. Selection of samples at random.
3. Multiple analysis of representation on thermochemical topics

3. Result and discussion
From the five samples of textbooks that have been analyzed, it was found that there are 3 labels of major concept for multiple representations on the topic of thermochemistry, namely exotherm reaction, endotherm reaction and enthalpy change. A more detailed explanation of the three labels concept found is as follows:

3.1. Exotherm reaction
The first labels concept is the reaction of the exotherm. From the five textbooks that have been analyzed, they explained the reaction using the exotherm reaction image phenomenon which results in heat. As for flying the space shuttle, it needs considerable energy which is about $2 \times 10^{10}$ kJ. The burning of the $\text{H}_2$ in $\text{O}_2$ used to gain 1/6 of the energy required, and the rest as much as 5/6 part of the explosion comes from the decomposition of ammonium perchlorate which is a solid fuel in the space shuttle (Textbooks 1). Two of five textbooks describe the reaction of the exotherm reaction through to the disaster that ever happened, that is a textbooks 2 and 3. Textbooks 2 used the disaster that happened in New Jersey Heidenberg, in 1937, where an aircraft filled with hydrogen is destroyed causing a spectacular explosion. The textbooks 3 described exotherm reaction through forest burn. Textbooks 4 described the reaction of the exotherm through the reaction between aluminum powder with iron (III) oxide which frees 16 kJ of heat per 1 gram of aluminum that burned as well as the reaction of phosphorus with red liquid bromine. Next, textbooks 5 explains the reaction that occurs in the manufacture of calcium hydroxide solids $\text{CaO}$ with water which produces $\text{Ca(OH)}_2$ as shown on a textbook 5 and shown by figure 2 below.

Figure 2. The reaction of $\text{Ca(OH)}_2$ formation.

Figure 2 shows that the reaction between $\text{CaO(s)}$ with $\text{H}_2\text{O(l)}$ will raise the temperature up to 40.5°C. This indicates that the reaction is the formation of $\text{Ca(OH)}_2$. The heat resulted by the system moves into the environmental system. In this reaction system temperature is higher than the temperature of the environment, so that the resulting system heat flow system to the environment. Macroscopic phenomena such as these are used for the development Intertextual learning strategies-based POE because it is easy to be directly observed as listed in figure 2. In addition, the materials used are easily obtained, so research can certainly be implemented the research can unquestionably be conducted.

Submicroscopic level, all textbooks explain the concept of reaction of exotherm by using a descriptive approach which shows that the reaction occurs and is followed by changes in heat. If heat is
absorbed less than on the heat released by the system to the environment then the reaction is known as the exotherm. Meanwhile the symbolic level is explained by the use of the equation of a chemical reaction, such as \( \text{CH}_4(g) + 2\text{O}_2(g) \rightarrow \text{CO}_2(g) + 2\text{H}_2\text{O}(l) \quad \Delta H = -890 \text{ kJ} \) (textbooks 2 and 5) and \( 4^{th} \) textbooks \( \text{CO}(g) + \frac{1}{2} \text{O}_2(g) \rightarrow \text{CO}_2(g) \quad \Delta H = -283.0 \text{ kJ} \), as well as textbooks 5 \( \text{CaO}(s) + \text{H}_2\text{O}(l) \rightarrow \text{Ca(OH)}_2(aq) + \text{heat} \). In addition to 5 textbooks is also represented through the diagram energy levels and the visualization system in releasing or receiving heat. One example is the energy level diagram as shown in figure 3 below.

**Figure 3.** An exothermic process in \( \text{Ca(OH)}_2 \) process.

Figure 3 Reveals that the reactions between \( \text{CaO}(s) \) dan \( \text{H}_2\text{O}(l) \) require a smaller energy compared to the heat that is released so that the temperature of the reaction around the system will heaten. This reaction is called as the exotherm.

### 3.2. Endotherm reaction

The second concept labels is an endotherm reaction. Of the five textbooks which have been analyzed to explain a reaction using the endotherm image to the phenomenon of reaction that absorbs heat. 3 of the 5 textbooks, textbooks 1, 2 and 3 describe the reactions endotherm reaction through reactions occurring between \( \text{Ba(OH)}_2 \). \( 8\text{H}_2\text{O} \) with \( \text{NH}_4\text{Cl} \). next textbooks 3 through the \( \text{HgO} \) warming reaction decomposes to \( \text{Hg} \) and \( \text{O}_2 \). In addition to the textbooks describes the phase change phenomena \( \text{H}_2\text{O} \) from a solid into a liquid. as shown on the textbooks of 1.4 and 5 for the next shown in figure 4 below.

**Figure 4.** An endothermic process when, \( \text{Ba(OH)}_2.8\text{H}_2\text{O} \) and \( \text{NH}_4\text{Cl} \).

Figure 4 shows that the reaction of \( \text{Ba(OH)}_2.8\text{H}_2\text{O}(s) \) and \( \text{NH}_4\text{Cl}(s) \) lowering the temperature of the mixture decreased at the 5.8°C, this indicates that heat transfer occurs from the environment to the system That is then called the endotherm reaction. Macroscopic Phenomena such as these are used for the development of Inter textual learning strategies based POE, because it is easy to be directly observed as listed in figure 4. In addition the materials used can be easily obtained, so study can be implemented well.

Five textbooks describe the level of submicroscopic to the concept of an endotherm reaction using a descriptive approach which shows that the reaction occurs and is followed by changes in heat. If heat is
absorbed at a temperature greater than that released by the system to the environment then the reaction is known as the endotherm. While the symbolic level is explained with the use of the equation of a chemical reaction, \( \text{Ba(OH)}_2.8\text{H}_2\text{O}(s) + 2\text{NH}_4\text{NO}_3(s) \rightarrow \text{Ba(NO}_3)_2(s) + 2\text{NH}_3 \) and energy + 2HgO(s) \( \rightarrow \) 2Hg(l) + O\(_2\)(g) (textbooks 1, 4 and 5). In addition to the 5 textbooks also describes the reaction of endotherm with as well as diagram energy levels and the visualization system in releasing or receiving heat. energy level diagram and Visualization system in releasing heat which is shown in figure 5.

![Enthalpy Diagram](image)

**Figure 5.** Endothermic process in \( \text{Ba(OH)}_2.8\text{H}_2\text{O}(s) + \text{NH}_4\text{NO}_3(s) \) reaction.

Figure 5 for reacting \( \text{Ba(OH)}_2.8\text{H}_2\text{O}(s) + \text{NH}_4\text{NO}_3(s) \) and producing \( \text{Ba(NO}_3)_2(s) + \text{NH}_3(g) \) the energy from the surrounding environment is needed, therefore it is named endotherm

3.3. Enthalpy change

Level concept to 3 is enthalpy. The five macroscopic textbooks that have been analyzed showed that enthalpy was described through calorimeter experiments, either calories or bomb meter simple calorimeter known as calorimeter cups of coffee. In general, the enthalpy changes occurred because the temperature can be calculated by using the formula \( \Delta H = m \cdot c \cdot \Delta T \). This experiment is best used to the development of Intertextual learning strategies based POE, since almost all laboratories have this tool. If none exists we can make it at a cheaper price as shown in figure 6.

![Calorimeter Diagram](image)

**Figure 6.** Coffee-cup calorimeter (textbooks 5).

Figure 6 explains that the calorimeter can be made from a simple tool, using a used coffee cup/noodles, thermometers and autoclave. So if in the laboratory did not have calorimeter, It can be easily made by using leftover materials that are all around us, Besides, it also a low-cost experiment. It was also found from the study that the level of sub microscopic was presented in the form of an explanation that the energy released by the system is equal to the energy that is absorbed by the environment. Meanwhile, the symbolic level for enthalpy change was formed through calculation using data \( \Delta H \) (standard formation enthalpy, \( \Delta H^{\circ}_{\text{reaction}} = \sum \Delta H^{\circ}_{\text{product}} - \sum \Delta H^{\circ}_{\text{reactant}} \)) and average bond energy.
The analysis results are used for the development of learning strategies Intertextual-based POE. For the purposes of intertextual based POE strategy development, then the concept of exotherm label at the macroscopic level being used is the mixing between CaO(s) with H₂O(l) which produces Ca(OH)₂ as shown on a textbooks 5. Mixing between Ba(OH)₂.8H₂O with NH₄Cl for endotherm concept furniture as shown in textbooks 1, 4 and 5. As for the concept of enthalpy change using experiments using the calorimeter (∆H = mcΔT). These three phenomena are chosen because they are synonymous with POE syntax consisting of predict, observe and explain, because it can be done through experiment. By experimenting all POE syntax can be performed, and by experiment students can understand the thermochemical material at the macroscopic level. Meanwhile, through calculations and drawings can clarify students’ knowledge at submicroscopic and symbolic levels.

4. Conclusion
From the analysis towards five textbooks of it was found that on the topic of Thermochemistry-consists of 3 main concepts namely exotherm reaction, endotherm reaction and enthalpy change. The macroscopic level to the concept of exotherm reaction appears in the form of phenomena such as combustion gas C₂H₂, Ca (OH)₂, the formation of Al₂O₃, a reaction of Fe₂O₃ with Al, and red phosphorus with bromine liquid. meanwhile, for endotherm reaction, it appears in the form of phenomena such as the decomposition reaction of Hg₂O, mixing between the Ba(OH)₂.8H₂O with NH₄Cl, as well as reaction decomposes of H₂O. At submicroscopic, all the books explain the reactions of exotherm and endotherm by using a descriptive approach which shows that the reaction occurs and is followed by changes in heat. In addition, in the symbolic level, the reaction was described using the equation of a chemical reaction, a diagram of the energy levels and the visualization system in releasing or receiving heat. Meanwhile, macroscopic representation to the concept of enthalpy change is presented by calorimeter experiment (ΔH = m.c.ΔT) which was later explained by representations of submicroscopic, that the energy released by system is equal to the energy accepted by the environment that was also completed by the symbolic level in the form of calculation by using the data of ∆Hf and average bond energy.

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