Research Article

Content Analysis of Chemistry Textbooks in the Chapter on Thermochemistry

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Abstract.
This study aimed to analyze the aspects of the general chemistry textbook in the chapter on thermochemistry. We reviewed three general chemistry textbooks commonly used in basic chemistry courses. This study used a qualitative approach by content analysis. The focus of this study was the thermochemistry chapter because this topic was considered to be difficult by students. Data analysis was carried out descriptively by combining similar data within the chemical literacy framework. The analysis results indicated that the three textbooks fulfilled most of the chemical content knowledge indicators, except for chemistry as an experimental discipline. The textbooks provided insights that chemistry can be used to explain phenomena in everyday life, to make decisions and participate in social debates on chemistry-related issues, and to understand the relationship between innovations in chemistry and sociological processes. The textbooks also presented knowledge that can encourage the enhancement of high-order learning skills, particularly in the review problems section.

Keywords: chemistry, textbook, thermochemistry

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1. INTRODUCTION

Chemistry is central to science, an interesting statement because many natural phenomena and human activities can be explained through chemistry. The claim first became popular with the publication of the first issue of Brown and LeMay's Chemistry: The Central Science, although this claim of centrality dates to the early 19th century when Justus von Liebig stated, "that everything is chemistry" [1]. The implication for education is that students in various disciplines need to learn how to explain, predict, and control the material's behavior that consists of everything in their environment [2]. However, various groups have not widely realized the benefits of chemistry. Non-chemists think that science is capable of producing knowledge that seems absurd [3].

Moreover, research shows that there is chemophobia among people [4]. The perception of chemicals in modern society is very complex. Chemicals are only seen from the point of view of being safe and dangerous. It also tends to be interpreted pejoratively; chemicals are associated with potential hazards to human health [5].

Misconceptions in chemistry are caused by ineffective communication between chemists and the public. The strategy for building this communication is education. One of the solutions to deal with chemophobia is strategic and structured chemistry education programs, focusing on the basics of chemistry and emphasizing the benefits of chemical products [4]. It is one aspect of chemical literacy. Literacy has become an essential topic in the last few decades. Literacy skills help a person to be able to express their mind, solve problems, process new information and understand the world around them properly [6]. The fundamental goal of teaching chemistry is to develop chemically literate citizens who are more informed and understand reports, chew over chemistry in the media, and better understand environmental issues (Shah & Sharma, 2014). A chemical literate person must understand basic scientific concepts, such as chemistry is a branch of science and involves theories that help explain nature. Knowledge gained from the study of chemistry can be transferred and applied to other topics in science and technology [7]. Through chemical literacy, the discipline of chemistry will find new directions and challenging opportunities for a better world to solve the problems that arise from the increasing gap between the rich and the poor, the human population, and migration [8].

Chemical literacy development for all students can be facilitated through content planning and professional teaching of chemistry courses [9]. The selection of appropriate textbooks is content planning. A textbook is not just a medium for disseminating information but has a role in mediating politics about what is taught and what methods to teach students [10]. Textbooks impact learning processes and outcomes because uniform ideas presented in them can affect student learning directly or indirectly [11, 12]. Research shows that science textbooks form the primary content and emphasis of science curricula, as well as the nature and scope of instructional activities and discourses in most science classrooms [13–16]. Based on the issues, it is necessary to analyze the textbooks used in learning, one of which is general chemistry textbooks.

Basic or general chemistry is a prerequisite course for students taking chemistry as a major subject. It serves as a gateway that is the first science course college students must take [17]. Thus, integrating chemical literacy into the course becomes a necessary strategy for optimizing chemical literacy development by making lecture material covering aspects of chemical literacy. There are diverse chemistry textbooks written by chemists with unique designs and characteristics. Lecturers need to sort and select textbooks carefully. Studies that compared various chemical textbooks, especially on the chemical literacy aspects, are still scant. Meanwhile, this step of the study is crucial as guidance for lecturers in choosing the teaching materials that enhance the content, context, and higher-order learning skills. The previous studies of textbook analysis tend to explore the concept of learning and how the idea was integrated, non-textual elements in textbooks, visual representations, learning content, or commentary of learning texts [18]. Research on science textbooks mainly investigates science literacy, especially in the Nature of Science (NOS) [19–23].

Therefore, this study aimed to analyze three general chemistry textbooks to determine the emphasis given to three domains of chemical literacy: (a) scientific and chemical content knowledge, (b) chemistry in context, and (c) high-order learning skills. In addition, this analysis was done in the thermochemistry chapter. Students assume the thermochemistry concept was difficult to learn and abstract [24, 25].

2. RESEARCH METHOD

The study used the qualitative content analysis method. Content analysis is the research technique used to formulate conclusions from the text to the context of its use that is replicable and valid [26, 27]. Qualitative content analysis is a research method for making subjective interpretations of the content of text data through a systematic classification process, coding, and identifying themes or patterns [28]. Source of codes of the study derived from chemical literacy theory. General or basic chemistry textbooks were selected as the sample in this study because the basic chemistry course is crucial for chemistry students, both chemist candidates, and pre-service chemistry teacher students. The sample consisted of three chemistry textbooks that were published by international publishers and used by Indonesian chemistry students. The sample selection is based on module handbooks from ten departments of Bachelor of Education in Chemistry. Table 1 lists the textbooks that were included in this study.

Table 1: The textbooks included in the study.

Title	Published Year	Number of Total Pages	Number of Thermochemistry Chapter Pages
Principles of General Chemistry 2^{nd} edition [29]	2012	918	40
Chemistry: The molecular nature of matter [30]	2012	1230	49
Chemistry [31]	2010	1170	45

By the research method used, data analysis was carried out descriptively by combining similar data within a specific conceptual framework or coding [32]. The chemical literacy coding scheme was created according to the definition of chemical literacy proposed by Shwartz, Ben-Zvi, & Hofstein [9] that is limited to three domains that are scientific and chemical content knowledge, chemistry in context, higher-order learning skills, and affective aspects. In this study, the scientific and chemical content knowledge domain was expressed by chemistry as an experimental discipline; chemistry is multidisciplinary; chemistry investigates energy changes, process dynamics, and chemical reactions; and uses multi representations. Chemistry in context was referred to by chemistry to explain everyday phenomena, chemistry helps people be aware of new products and technologies, and chemistry supports citizen literacy development. Higher-order learning is limited to finding other information, connecting information, and analyzing the advantages and disadvantages of a product or technology.

3. RESULT AND DISCUSSION

In chemistry, energy must be understood at the atomic and molecular level and is typically introduced in terms of particles' potential and kinetic energy [33]. Consequently, students have difficulties understanding thermochemistry topics. A solution to solve the problem is to use appropriate textbook integrated chemical literacy. The study analyzes three general textbooks to give a picture representing chemical literacy.

Chemical Content Knowledge Analysis

Three textbooks do not fulfill the aspects of chemistry as an experimental discipline . The books contain a calorimeter used to measure heat changes in chemical reactions. The textbooks describe calorimeter components, how it works, and how to analyze data. There are diverse meanings for the term" experiment." The experiment can mean subject content, pedagogy, scientific processes, and inquiry separately or simultaneously [34]. The four roles indicate that experiments are active processes and not just related to the use of laboratory equipment. The accuracy in measuring a variable, heat, is only one aspect of science process skills [35]. The missing aspects include observing, classifying, predicting, and inferring.

Chemistry can be multidiscipline, providing knowledge used to explain phenomena in other fields; Multidisciplinary provides opportunities for students to gain a global knowledge base [36]. The issue is a crucial topic in science education, as well as chemistry. The three textbooks are multidisciplinary by describing intercorrelation chemistry and other disciplines, such as biology, physics, astronautics, and engineering. The list of

Table 2: List multidisciplinary issues in the textbooks.

Textbooks	Related discipline	Issues	Concepts
(Silberberg, 2012)	Physics	All other forms of energy transfer involve some work; the energy is transferred when an object is moved by force. When you inflate the ball, the air inside (the system) influences the inside walls of the ball (the surroundings) and works to move it outwards.	Chemistry: work, system, and surrounding Physics: forces
(Jespersen, et al., 2012) (Silberberg, 2012) (Chang, 2010)	Biology	In photosynthesis, green plants convert radiant energy from the Sun into chemical energy, converting low-energy CO_2 and H_2O into high-energy carbohydrates and O_2. When wood is burned in the air, those low-energy compounds are formed again, and the energy difference is released into the environment.	Chemistry: heat, chemical reaction Biology: plant metabolism
(Jespersen, et al., 2012) (Silberberg, 2012) (Chang, 2010)	Engineering	When gasoline or hydrocarbon fuel burns in a car engine, the energy released appears as an equivalent amount of heat and work. The heat warms the car's parts, the passenger compartment, and the air around it. The work appears as mechanical energy to turn the wheels and belts of the vehicle.	Chemistry: heat and work Engineering: automotive
(Jespersen, et al., 2012)	Astronautics	The explosive reaction between hydrogen and oxygen in the shuttle's main engine produces light, heat, and expanding gasses that help lift the space shuttle off its launch pad.	Chemistry: heat, chemical reaction Astronautics: shuttle's engine
(Chang, 2010)	Engineering	Utilization of dam water for hydroelectric energy generation. When waterfalls over a dam, its potential energy is converted into kinetic energy.	Chemistry: Law of energy conservation Engineering: electricity

multidisciplinary topics is presented in Table 2. The table draws the relationship between chemistry and other disciplines, i.e. physics, biology, engineering, and astronautics.

Chemistry investigates energy changes, process dynamics, and chemical reactions. Chemistry has been portrayed as a discipline studying the matter and its characteristics. Everything related to matter was explored in chemistry, such as energy changes, process dynamics, and chemical reactions. The three textbooks predominantly discuss energy changes and chemical reactions since thermochemistry deals specifically with energy and energy transformation in chemical reactions to reason it out.

Chemistry has a unique language [9]. Multirepresentation consisting of three levels of representation becomes a language to describe phenomena happening in chemical reactions and energy changes. Macroscopic, symbolic, and sub-microscopic levels were laid out in the textbooks in textual and pictorial. They are presented by both individuals and combined, as seen in Fig 1.

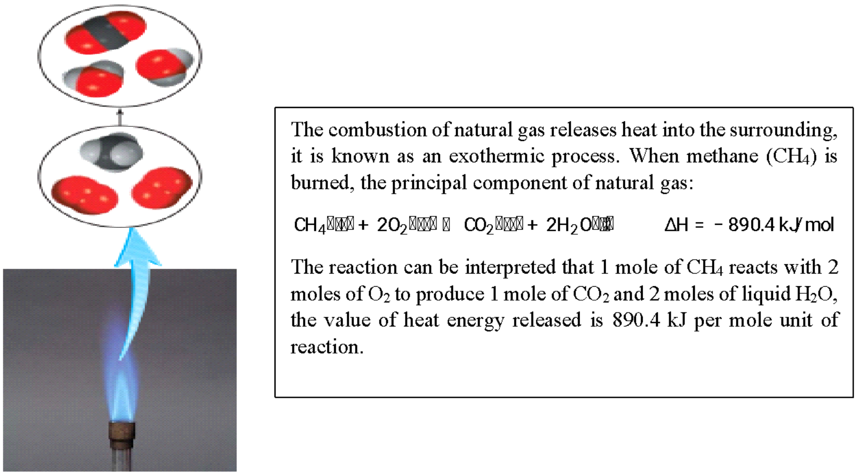

Figure 1: Integration of macroscopic, symbolic, and sub-microscopic in the combustion of methane both in textual and pictorial (source: Chang, 2010)?.

3.1. Chemistry in Context Analysis

Chemically literate people are curious about chemical phenomena and try to satisfy that curiosity [37]. Connecting everyday processes with the chemical point of view will foster students' interest in chemistry [38]. All the textbooks describe the implementation of thermochemistry in life, the following example:

1. Whenever matter changes, the energy content of matter also changes. When a candle burns, the reactants, wax, and oxygen, contain more energy than the product, gasses CO_2 and H_2O, then the energy gap is released as heat and light. In contrast, reactions N_2 and O_2 in the air produce NO absorb energy in a lightning flash [29].

2. Water serves as a thermal cushion for the human body. The adult body is about 60% water by mass, so it has a high heat capacity. Therefore, the body can exchange considerable energy with the environment but experience only a tiny temperature change. This makes it relatively easy for the body to maintain a steady temperature of 37°C, which is vital to survival. With a substantial thermal cushion,

the body adjusts to significant and sudden changes in outside temperature while experiencing tiny fluctuations in its core temperature [30].

3. If you have ever pumped air into a bicycle tire, you probably noticed a warming effect at the valve stem. The first law of thermodynamics can explain this phenomenon. The action of the pump compresses the air inside the pump and the tire. The process is rapid enough to be treated as approximately adiabatic, q = 0 and ΔE = w. Since work is done on the gas in this case (it is being compressed), w is positive, and energy increases. Hence, according to the equation,the system's temperature increases [31].

Chemical literacy is the basic chemical knowledge that is useful and essential for life, especially in modern technological society [39]. When a product is made, chemistry plays a role in materials, processes, and packaging [40]. Most the textbooks present this aspect in the last of the chapter, and only a few examples are exposed, the following example:

1. (a) Fuel cells related to climate change. In recent decades, changes in the earth's climate are increasingly apparent. This is caused by using carbon fuel which, when burned, will release CO_2 into the air. CO_2 in the atmosphere does not absorb visible light from the sun but traps some of the heat radiating back from the earth's surface and, in doing so, helps warm the atmosphere. However, the increasing number of burning carbon fuels causes the amount of CO_2 in the atmosphere, resulting in a significant amount of heat trapped in the atmosphere [30]. This creates an enhanced greenhouse effect that changes the climate through global warming

   (b) A runaway reaction occurred in a reaction vessel in a dye manufacturer. Most chemical reactions are exothermic. The heat given off by the reaction will raise the temperature of the reaction mixture unless it is removed. The heat may be removed through ordinary losses to the surroundings by deliberate cooling. However, if this vent is not large enough, the pressure will eventually cause the vessel to rupture, releasing a mixture of liquid and vapor. An explosion and fireball can result if the vapor cloud is flammable and finds an ignition source. To prevent runaway reactions and their potentially disastrous results, it is essential to know how much heat a reaction will release, how fast it is released, and how quickly it can be removed from the reaction equipment [31].

(c) Making snow. How is this stuff made in quantities large enough to meet the needs of skiers on snowless days? The secret of snowmaking is in the equation $\Delta E = q + w$. A snowmaking machine contains a mixture of compressed air and water vapor at about 20 atm. Because of the significant difference in pressure between the tank and the outside atmosphere, when the mixture is sprayed into the atmosphere, it expands so rapidly that, as a good approximation, no heat exchange occurs between the system (air and water) and its surroundings; that is, q=0 [32].

When people are aware of products and technology, it is expected to foster citizen literacy development. Citizen literacy enhances students' competencies to deliberate multiple concepts and arguments to solve national or global problems from different points of view [41]. Thus, chemistry supports the citizen literacy development aspect related to two previous parts in the context domain. The picture of chemistry and citizen literacy in the textbooks was shown implicitly.

Higher-Order Learning Skills

Textbooks can represent competencies that are expected to develop in students. A textbook has a lot of questions or statements that can be used to encourage the student to think in a higher domain, such as analytical and critical thinking. Developing higher-order learning skills in students can be identified by students' competencies to examine the drawbacks and benefits of a product or technology by finding and connecting the relevant information. Three textbooks carry out this domain in the review problems section. The other section units conduct content and context aspects. The portion of higher-order questions presented in the textbooks is around 50

4. CONCLUSION

The textbooks selected in this study enact the majority aspects of three domains of chemical literacy, chemical content knowledge, chemistry in context, and higher-order learning skills in the thermochemistry chapter. One aspect lacking in the three textbooks is chemistry as an experimental method because the nature of the experiment needs an explanation of the process and method, not just showing a calorimeter and its parts. Integration of chemical content knowledge and chemistry in context are generality detailed in the body of the chapter. In contrast, the higher-order skills domain is enacted in review problems sections. The textbooks reviewed can be employed to develop students' chemical literacy or to be used as a reference by lecturers when they draw up chemical literacy for assessment and learning materials. Finally, it is suggested that the future version of the textbooks can illustrate experimental activities more clearly and improve the number of contextual cases.

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