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A CONTENT ANALYSIS OF PICTORIAL MATERIAL IN THE CHEMISTRY TEXTBOOKS ON THE TOPIC REDOX REACTION BASED ON CHEMICAL REPRESENTATION

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ABSTRACT

Chemical representations can assist learning in understanding abstract concepts. Images can transform complex information into a form that is easier to interpret and understand. Therefore, the requirement of visual representations in chemistry textbooks is beneficial and necessary to enhance understanding of chemistry. This qualitative descriptive study analyses pictorial material related to redox reactions in chemistry textbooks based on chemical representation. This study analyzed three chemistry textbooks for 10th senior high school from different publishers that met the criteria in the purposive sampling specified. The three books contain topic redox reactions, 2013 curriculum, already have an ISBN, are used by schools, and have interesting pictures or illustrations. The instrument was developed based on the five criteria for chemical representation. Cohen Kappa coefficient was used to measure inter-rater agreement. The results show this study has an almost perfect agreement (0,891). The pictorial material in the three textbooks has macroscopic, submicroscopic, multiple, and mixed types of visual representation. The study analyzed the pictorial material or visual content in three chemistry textbooks (books A, B, and C). The results showed that the type of visual representation with the highest percentage was macroscopic, which was 58.33% in book A, 50% in book B, and 57.14% in book C. The highest proportion of ambiguous interpretation of surface features was found in topic redox reaction compared to other typologies, which was 50% in book A, 50% in book B, and 57.14% in book C. Most of the images in the textbooks were completely related and linked to the text and had image captions. The textbooks had a high level of relatedness to the text, with completely related-linked percentages of 66.67% in book A, 70% in book B, and 57.14% in book C. The study found that the pictorial material presented in the three books met the standard criteria of chemical representation. The study's findings can be used as a reference for teachers to determine student learning resources for chemistry textbooks with appropriate chemical representations, which can help improve students' understanding of the subject.

Keywords: Content analysis, Chemical representation, Pictorial material, Chemistry textbook, Redox

INTRODUCTION

Chemistry studies the composition, structure, properties, changes in matter, and energy accompanying these changes [1]. It belongs to the natural sciences. Chemistry is a science close to everyday life and should

be easy to accept and learn. But chemistry is often classified as complex because some materials have abstract concepts [2,3]. So makes it difficult for students to imagine or experience directly [4]. In addition, the content in chemistry lessons includes coherent material. If students do not understand the material that is the basis of other material, they will have difficulty understanding the following content. For example, students at the beginning of learning cannot understand the difference between oxidation and reduction reactions; it will be difficult to understand the material in the next level of material, electrochemistry.

According to Johnstone, understanding chemistry requires three representation levels of thinking to see chemical phenomena, namely macroscopic, submicroscopic and symbolic representations [5-7]. Macroscopic representation refers to phenomena or things the human senses can observe directly [6,8]. Submicroscopic representation refers to things that happen at the molecular level because they are too tiny to be observed, such as electron movements [6,8]. Symbolic representation refers to how a phenomenon is symbolized with symbols, letters, numbers and signs [6]. Chemical representations can be used as a tool in studying, understanding, analyzing and solving problems of abstract concepts in chemistry and relating them to existing chemical phenomena [9,10]. Students can form a well conceptual understanding by understanding the three existing representations [11]. However, it is not easy because students are used to thinking at a macroscopic level. Students will be more interested in the lesson if the material is related to them and can do it directly with the senses (macroscopic). For example, students will find it difficult to imagine the reaction of a substance with oxygen (oxidation reaction) if only from a symbolic perspective. It is different if students are given examples of direct events that occur in daily life. For example, the teacher can explain the oxidation reaction using iron rusting. Students are invited to review how the rusting process on iron that they usually see daily can occur from the submicroscopic side. The change occurs due to interactions between Fe and O molecules or atoms. Explanations can be supported by writing down the reactions that occur in symbols to strengthen students in terms of theory or concept. So the teacher needs to be able to explain the material by connecting the three representations. Therefore, this also needs to be supported by appropriate textbooks.

Abstract concepts in chemistry are difficult to imagine or experience directly with students. It can be visualized or explained more easily with the help of pictures that support the text. In other words, images can transform complex information into a form that is easier to interpret so that it is easier to understand [6]. In addition, the presence of pictures can be a technique that makes the material more memorable for students to remember. Making text illustrations into images in textbooks requires more consideration because the presence of images may give the wrong meaning of the expected information. The illustrated material in the books must be supportive and interrelated and related to the existing textual

material so that it helps in the understanding process with visualization [6,12]. Therefore, visual representation is beneficial in the process of understanding chemistry. For this reason, the presence of pictorial material is quite impactful and needs to be considered in textbooks.

Oxidation-reduction or redox reactions are contextual materials that are considered difficult in school. Students need to understand how reduction and oxidation occur without seeing the gain or loss of electrons or oxygen (in molecular) and linking it with another concept, namely the oxidation number [13,14]. Students also have misconceptions because most students assume that oxidation reactions always involve oxygen, thus affecting the study of oxidation numbers [13]. In addition, De Jong and Treagust [15] also stated that the difficulty in topic Redox reactionwas because some students considered reduction and oxidation reactions separate reactions. Chemical representations can make it easier for students to understand the redox process. So chemical representations need to be presented in textbooks.

Students' difficulties in learning concepts in chemistry come from the course of the learning process, and the textbooks used [3,16,17]. Even so, textbooks are an important component in learning, either as learning media or as learning resources. Textbooks must facilitate students understanding of chemical concepts [17]. Several previous studies conducted regarding the analysis of the content of chemistry books based on chemical representations found that chemistry textbooks used in schools do not fully involve chemical representations well [3,9,17]. Textbooks only focus on two levels of representation, and almost all books focus on symbolic representation. Based on the results of previous studies and the importance of the presence of chemical representations in the textbook, researchers conducted a study to see how the presence and presentation of chemical representations in chemistry textbooks on the material [9].

Criteria for evaluating chemistry representation in textbooks have been proposed to aid in designing and evaluating new textbooks [6]. Based on the chemical triangle, these criteria include five elements: type of representation, interpretation of surface features, relatedness to text, existence and properties of a caption, and degree of correlation between representations comprising multiple ones. These criteria cover essential elements for enhancing students' understanding of chemistry. This study analyses pictorial material related to topic redox reactionin chemistry textbooks based on chemical representation and provides information for teachers in selecting appropriate learning resources.

METHODS

Research Design

This research uses a content analysis approach to analyze pictorial material related to Redox in chemistry textbooks based on chemical representation. This research aims to describe and analyze the type and proportion of chemical representations in topic redox reactions high school chemistry textbooks and the

relationship between the pictorial material and text based on five criteria [6]. The study used three chemistry textbooks for the 10th of the senior high school curriculum 2013 from different publishers that already have an International Standard Book Number (ISBN) and are commonly used in Surakarta. The data collection method in this study is documentation, where pictorial material found in the topic of Redox of chemistry textbooks was collected and documented using a code that aims to facilitate the search and analysis process. The research design is shown in Figure 1.

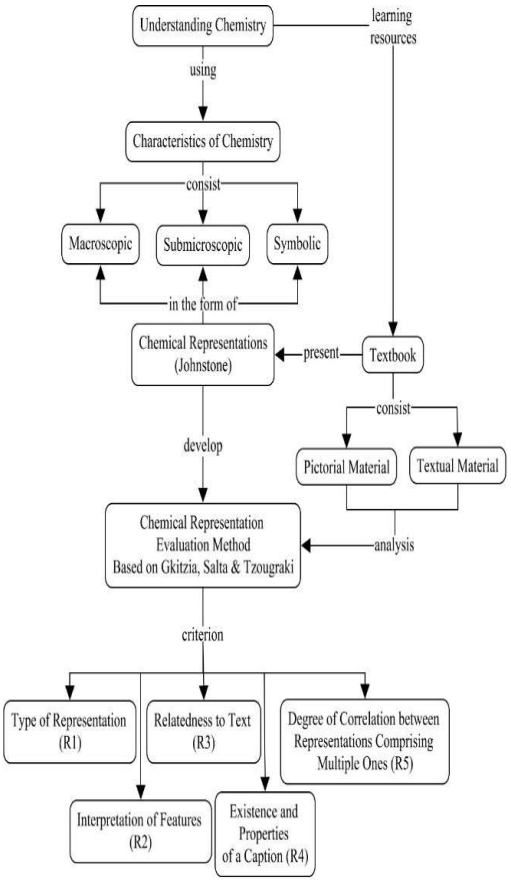


Figure 1. Flow chart of this research

Instrument and Collecting Data

The data collection instrument used in this study is an observation sheet created based on the chemical representation criteria proposed by [6]. The observation sheet consists of five criteria, namely type of representation (R1), the interpretation of surface features (R2), relatedness to text (R3), existence and properties of a caption (R4), and degree of correlation between representations comprising multiple ones (R5). In addition, each criterion has several typologies corresponding to specific chemical representation features. Two raters collected the data and independently analyzed the pictorial material in the chemistry textbooks. The raters put a mark (Π) on each appropriate chemical and typology representation criteria. The raters for this study were chosen based on their understanding of chemical representation. Rater 1 is one of the authors, and rater 2 is a chemistry teacher who has researched chemical representation.

Data Analysis

The data analysis in this study was performed using content analysis. First, the raters analyzed each textual and pictorial material based on the chemical representation criteria (R1-R5) by looking at the appropriate typology for each criterion. Next, the inter-rater agreement was measured using the Cohen Kappa coefficient. The results showed an almost perfect agreement (0.891) between the two raters. The analysis results were then presented descriptively in tables and graphs to describe the type and proportion of the presence of chemical representations in topic redox reactions high school chemistry textbooks and the

relationship between the pictorial material and text based on five criteria. The results of this study are expected to provide information to teachers to choose which books are most suitable for learning resources.

This study provides a detailed and systematic method for analyzing pictorial material related to redox reactions in chemistry textbooks based on chemical representation. Using two raters and the Cohen Kappa coefficient ensures the reliability and validity of the data analysis. The results of this study can be used as a reference for future research and as a guide for teachers in choosing appropriate learning resources.

RESULTS AND DISCUSSION

The pictorial material is analyzed to determine whether the image material supports the textual material of the existing textbooks [12]. This study analysed pictorial material based on the chemical representation with the criteria [6]. The development of criteria consists of five criteria. Each criterion has a typology to evaluate twice the representations individually and subsequently discuss their evaluations. A total of 36 pictorial materials related to redox reactions were identified in the three chemistry textbooks. The results of the analysis of the percentage of pictorial material in chemistry textbooks based on chemical representation [6] can be seen in Table 1.

Table 1. Analysis of Pictorial Material in the Chemistry Textbooks for 10th of Senior High School on Topic redox reactionbased on Chemical Representation [6].

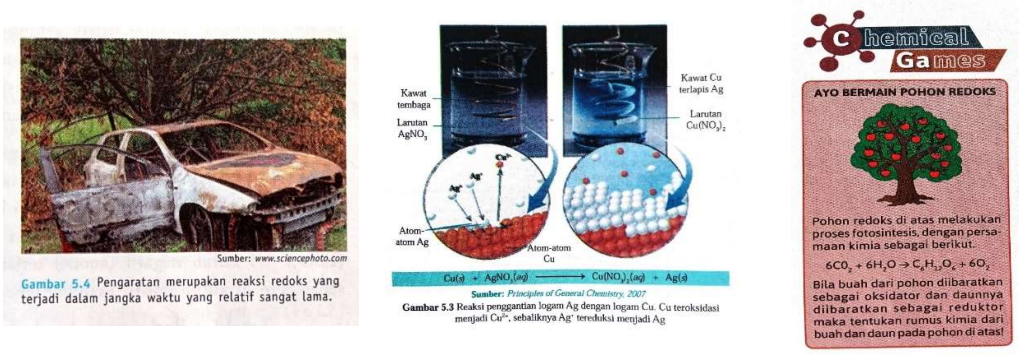
Typology	Book A (%)	Book B (%)	Book C (%)
R_1.macro	58,33	50	57,14
R_1.submicro	8,33	10	7,14
R_1.symbolic	0	0	0
R_1.multiple	25	40	35,71
R_1.hybrid	0	0	0
R_1.mixed	8,33	0	0
R_2.explicit	41,67	30	35,71
R_2.implicit	8,33	20	7,14
R_2.ambigous	50	50	57,14
R_3.completely related and linked	66,67	70	64,29
R_3. completely related and unlinked	0	0	7,14
R_3.partially related and linked	16,67	20	21,43
R_3.partially related and unlinked	0	0	0
R_3. unrelated	16,67,	10	7,14
R_4.existence of appropriate caption	58,33	50	42,86
R_4.existence of problematic caption	8,33	20	7,14
R_4.no caption	33,33	30	50
R_5.sufficiently linked	66,67	50	80
R_5.insufficiently linked	0	50	0
R_5.unlinked	33,33	0	20

The study analyzed 36 pictorial materials from the three chemistry textbooks, with book A containing 12 representations, book B containing 10, and book C containing 14. The proportion of each typology criterion that appeared in the topic redox reaction of each book was calculated by dividing the number of representations under a specific typology by the total number of representations that fit a specific criterion and then multiplying the result by 100 [19]. Table 1 presents the percentage values obtained from this calculation, which enables us to observe the proportion of each typology criterion that appears in the topic redox reaction of each book.

Based on the analysis of the pictorial materials and the results obtained, it is possible to determine whether the position of the pictorial materials in the material supports and relates to the text of the material or if it is purely decorative [6,12]. According to criterion R3, which focuses on relatedness to text, all three books show complete linkage and relation between the pictorial and textual material. Moreover, the tendency of the picture material to be ambiguous is high, as indicated by the percentage of ambiguous typology. However, multiple representations, considered a good standard of this type of representation, also have a significant value [3,6].

Criterion R1: Type of Representation

The criterion of type of representation examines the level or types of representations present in the textbooks [6]. The different types of representation considered include chemical aspect/level, macroscopic, submicroscopic, and symbolic. The three chemical aspects have been further developed into different typologies, such as macroscopic, submicroscopic, symbolic, multiple/multiple, hybrid, and mixed. In the three books, macroscopic, submicroscopic, and multiple/multiple representations were found (as shown in Table 1), with the largest proportion being macroscopic representation. An example of a macroscopic representation can be seen in Figure 2a, which depicts a rusty car to explain redox events in everyday life. Symbolic and hybrid representations were not found in the three textbooks, but symbolic representations can be combined with other representations, as seen in Figure 2b. On the other hand, mixed representations only appeared in book A, where an analogy was used to represent the redox reaction in photosynthesis, using a fruit and a leaf (as shown in Figure 2c).



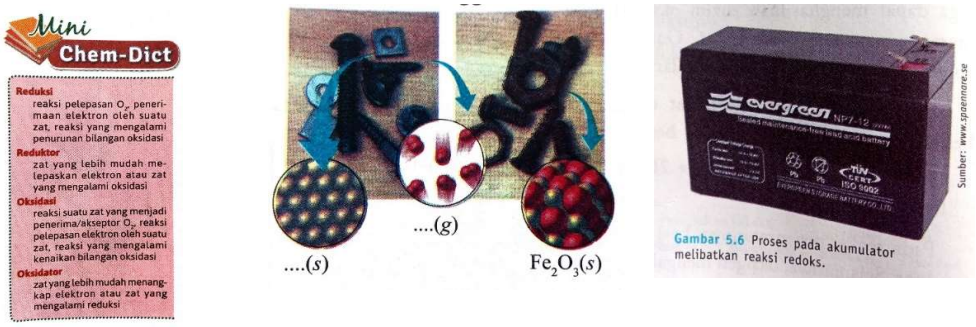
(a) (b) (c)

Figure 2. An example of the application of representation analysis (a) macroscopic representation [20], (b) multiple representation (macroscopic-submicroscopic-symbol level) [21], (c) mixed representation (macroscopic-symbol) [22].

Criterion R2: Interpretation of Features

Interpretation of features is a representation criterion that tests the clarity of the meaning of the representation of the image, especially if the image is only seen from the information displayed without going through the process of interpreting the meaning [6]. In the interpretation criteria, the representation feature (R2) has three typologies, namely i) explicit, ii) implicit, and iii) ambiguous [6]. A good visual representation is a representation that has explicit feature interpretations where the meaning of each image is clearly stated, or the meaning can be directly understood by only seen. The proportion with the largest percentage for interpretation of the surface is ambiguous in the three textbooks.

In Figure 3, image a, the description of the image contains the meaning of the image. While in Figure 3, image b, there are arrows connecting the difference and the atomic model, as well as the compound/element symbol providing help to understand the image but only partially, and a process is still needed to digest the image's meaning. And in Figure 3, image c is ambiguous because the accumulator image does not have a clear meaning where the image is displayed, so it is only for text complement.



(a) (b) (c)

Figure 3. An example of the application of representation analysis regarding the categories characterized as (a) explicit [22], (b) implicit [21], and (c) ambiguous [20].

Criterion R3: Relatedness to Text

Relatedness to text is a criterion that examines the clarity and connectedness or linkage of image representations with the content of textual material [6]. The pictorial material in the textbook must support the existing textual material so that it helps in the understanding process with visualization [12]. This criterion developed into several typologies, namely i) completely related and linked, ii) completely related and unlinked, iii) partially related and linked, iv) partially completely related and unlinked, and v) unrelated [6]. Most of the images in the textbooks are completely related and linked to the text. For example, the picture of experiment Cu and silver (Figure 4 image a) with text content has a fully related and related relationship where the text and image content explain the same thing, silver recycling. The picture shows the silver recycling process at the macroscopic, submicroscopic and symbolic levels.

(a) (b)

Figure 4. An example of the application of representation analysis regarding the categories relatedness to text : (a) completely related and linked [20], (b) completely related and unlinked [21].

Criterion R4: Existence and Properties of a Caption

The criterion of accompanying description or caption with an image is used to evaluate whether the sentence fits well with the image and whether any issues are present in it [6]. A caption is important as it can help clarify the content and message being conveyed and make it easier for students to understand the representation without having to refer to the related text. However, the relationship with the text is still necessary. For instance, regarding redox material, the percentage of visual representations with appropriate captions in Book A is 58.33%, Book B is 50%, and Book C is 42.86%. However, in Book C's redox material, the percentage of representations without any information is greater than those with information, which is 50%.

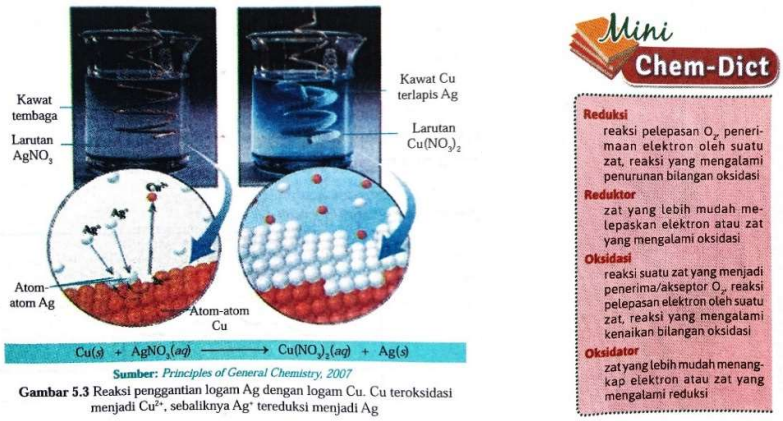
(a) (b) (c)

Figure 5. An example of the application of representation analysis regarding the categories (a) existence of appropriate caption [22], (b) existence of problematic caption [20], and (c) no caption [21].

Criterion R5: Degree of Correlation between Representations Comprising Multiple Ones

This criterion is tested if the type representation (R1) is identified as a multiple representation type. This criterion examines the relationship between two or three existing representations. The typologies in this criterion are i) sufficiently linked, ii) insufficiently linked, and iii) unlinked. Based on the results of research on the R1 criteria (representation type), it was found that material in the three chemistry textbooks for 10th senior high school,

each of them contained multiple representation types with the percentage of book A by 25%, book B by 40%, and book C by 35. ,71%. Furthermore, the multiple image representations that have been found are examined for their relationship (R5), and it is found that the type of multiple representations that are reasonably related in the topic redox reactionin book A is 66.67%, book B is 50%, and book C is 80%. In Figure 6, image a, multiple consisting of macroscopic, submicroscopic, and symbolic levels where the presence of each chemical level element explains each other, especially with the presence of arrows that help connect.



(a) (b)

Figure 6. An example of the application of representation analysis regarding the categories (a) sufficiently linked [21] and (b) unlinked [22].

The research results indicate that all three 10th senior high school chemistry textbooks contain representations that meet the standard criteria for good representation. These criteria include having multiple types of representations, clear and explicit meanings, being completely related and linked, having appropriate captions, and being sufficiently linked. An example of how the criteria were applied to analyze an image can be found in Table 2.

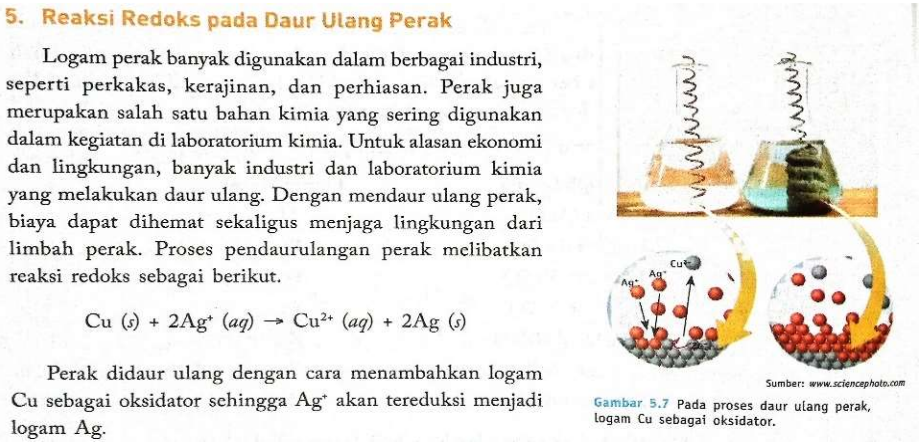


Figure 7. Example of the application of representation analysis

Table 2. Application of Analysis of Pictorial Material Based on Chemical Representation.

Criteria	Typology	Explanation
R1	multiple	Macroscopic from solution colour, Cu metal colour, precipitate. Submicroscopic of the aromatic spheres of Cu and Ag and their ions. Symbolic of the elements Cu, Ag and their ions.
R2	explicit	Information in the form of element symbols and arrows explains the image's meaning.
R3	completely related and linked	The experimental picture of Cu and silver is related to the text content, where it explains the content of the text and is related to the context.
R4	existence of appropriate caption	Pictures and descriptions have the same agreement, namely about the silver recycling process.
R5	sufficiently linked	Macroscopic, submicroscopic, and symbolic elements are interrelated to explain each other in the reaction process.

CONCLUSION

The three textbooks use macroscopic, submicroscopic, and multiple types of visual representation to illustrate redox material. Mixed representation is a type of visual representation found only in book A. Meanwhile, symbolic representation is found together with other types of representation so that it is included in the multiple representations in the analysis. The proportion with the largest percentage for the type of representation is macroscopic representation, while for interpretation of the surface is ambiguous in the three textbooks. Most of the images in the textbooks are completely related and linked to the text and have image captions. The three textbooks sufficiently link the largest percentage for the degree of correlation between representations comprising multiple ones. The findings show that the visual representation presented in the three books has met the standard criteria of chemical representation.

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