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Visual Representations in Indonesian Chemistry Textbooks: Supporting Deep Learning for 2025 Educational Goals

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ABSTRACT

Indonesian students struggle with abstract science concepts, as reflected in their low performance in international assessments. The primary learning resource is still textbook, and their visual materials are significant in helping students understand abstract concepts, especially in chemistry. However, visuals are often underutilized in science education. To address this gap, this study analyzes visual representations in Indonesian chemistry textbooks of the 2013 Curriculum to inform future improvements aligned with Indonesia's 2025 educational goals. Two widely used textbooks for grades X and XII were examined to explore differences across grades. Using qualitative content analysis and a modified rubric, the study reveals that symbolic visuals that have explicit surface features (such as chemical formula and equations) dominate, while macroscopic and sub-microscopic visuals are underrepresented. In relation to the text, most visuals are completely related with the content but not directly referred to in the text, which may hinder students' understandings. Positively, most visuals are contiguous (positioned close to the related text) with the related text and categorized as either with-caption or incorporated into text. These findings highlight gaps in textbook design, such as overreliance on symbolic visuals and poor visual-text integration. To support deep learning, textbooks should include multi-level visuals, ensure direct referencing, and provide clear captions. These changes are essential for fostering deeper understanding and aligning with Indonesia's 2025 educational goals, offering insights for improving textbook quality.

Keywords: *Chemistry, Deep Learning, Visual Representations, Textbooks*

INTRODUCTION

Chemistry studies abstract phenomena that are not always directly observable (e.g., atoms and molecules). Generally, chemistry phenomena can be represented in three levels: macroscopic (observable), sub-microscopic (particulate level) and symbolic (chemical symbols and equation) (Johnstone, 1993). Due to its abstract nature, many students struggle to connect these levels, leading to negative perceptions of the subject (Kapici, 2023; Shehab & BouJaoude, 2016; Wang et al., 2022).

In Indonesia, students consistently perform poorly in science assessments. According to PISA 2022 (Program for International Student Assessment), Indonesian students ranked 67th out of 81 countries, with 65% scoring below level 2 (OECD, 2023). It indicates that students face difficulties with abstract concepts. This poses a challenge for achieving deep learning, a key goal of Indonesia's 2025 educational framework, which emphasizes connecting learning to real-life scenarios, holistic thinking, collaboration, and empathy (Aranditio, 2024; Fullan & Langworthy, 2013). One way to address this challenge is through visual representations in textbooks, which can help students see intangible chemistry concepts in a more concrete way and connect the three levels of representation of chemistry phenomena (Devetak & Vogrinc, 2013; Johnstone, 1993). However, the simple presence of visuals in textbooks does not guarantee imrpoved understanding. Visuals should match students' needs and abilities (Gkitzia et al., 2011) and be accurately integrated with text to prevent confusion, especially for students with weaker prior knowledge (Nyachwaya & Gillaspie, 2016). This study focuses on chemistry textbooks from the 2013 Curriculum, which is still widely used and more stable than Kurikulum Merdeka. The 2013 curriculum also provides chemistry content across all grades, allowing for a more complete analysis.

Textbooks play a key role for both teachers and students. For teachers, they guide what and how to teach (Isaksen et al., 2024; Shahid et al., 2023), while for students, textbooks are the primary learning resources (Devetak & Vogrinc, 2013) especially outside classrooms (Nyachwaya & Wood, 2014). However, in chemistry, Gabel (1983) and Ruis (1988) have proven that textbooks often fail to explain qualitative concepts behind quantitative phenomena, such as chemical formulas, leading to rote learning. The quality of science textbooks, especially chemistry, needs to be assessed. It can be analyzed on three levels: general structure, textual aspect, and pictorial aspect (Devetak & Vogrinc, 2013). The pictorial aspect, which includes visual representations, is curcial for supporting students' understanding of scientific knowledge. Research shows that combining words and visuals is more effective than just texts (Devetak & Vogrinc, 2013; Mayer, 2002; Zenki-Dalipi & Osmani, 2022). Visuals are particularly important in chemistry, where many phenomena are not directly observable (Shehab & BouJaoude, 2016). Moreover, instructional guidance, such as captions and labels, assist learners to connect visuals with texts (Nyachwaya & Gillaspie, 2016) particularly those with limited prior knowledge (Mayer, 2003). Captions containing only one sentence are called labels. Index is the part where text directly links or mentions the visuals.

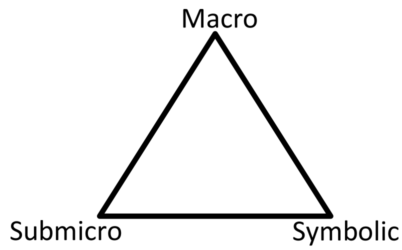


Figure 1. Three basic components of chemical phenomena (adopted from Johnstone (1993)

Johnstone's representation theory provides a framework for understanding chemical phenomena at three levels: macroscopic (tangible, observable phenomena), submicroscopic (abstract, particulate-level phenomena) and symbolic (chemical symbols, equations, and diagrams) (Johnstone, 1991; 1993). These levels are an inseparable whole to build a full understanding of chemistry concepts, illustrated by Johnstone (1991; 1993) with an equilateral triangle whose each corner indicates each level of representation (Fig. 1). The visual representations are significant in enhancing understanding of chemical phenomena.

However, the simple presence of visuals does not automatically guarantee improved understanding. Students must first understand macroscopic concepts before shifting to microscopic and symbolic levels (Kapıcı & Savaşcı-Açıkalın, 2015) because macroscopic visuals represent fundamental concepts (Herga et al., 2015; Johnstone, 2007). Multi-level visuals, which combine these representations, can build comprehensive understanding (Kapıcı &

Savaşcı-Açıkalın, 2015; Wang et al., 2022), but must be used carefully to avoid overwhelming students, especially with complex concepts (Treagust, 2007). Unnecessary detail or confusing elements in visuals can lead to misconceptions (Han & Roth, 2006; Mayer, 2009; Nyachwaya & Gillaspie, 2016). Unfortunately, many science textbooks only focus on symbolic representations especially chemical equations and formulae, encouraging rote learning rather than conceptual understanding (Bunce & Gabel, 2002; Talanquer, 2011).

Research has analyzed visuals using various criteria. Gkitzia et al., (2011) offer three criteria for analyzing representations in chemistry books: types of representation, interpretation of surface features, degree of correlation between the components comprising a multiple representation. While, some studies have examined visuals in Indonesian chemistry textbooks, they often focus their analysis only on particular topics (Addiin et al., 2016; Afifah et al., 2023; Mujibaturrahmi et al., 2022; Rahayu, 2014; Shopariah, 2014), leaving a gap in comprehensive analysis for the whole book especially for the implementation of 2025 education in Indonesia.

At the end of 2024, Indonesia's Minister of Primary and Secondary Education, Abdul Mu'ti, proposed implementing deep learning in primary and secondary education (Aranditio, 2024), inspired by Michael Fullan's approach (Fullan & Langworthy, 2013). Deep learning emphasizes three main aspects: *mindful, meaningful, and joyful learning.* Mindful learning encourages active engagement through discussion and experimentation, then meaningful learning focuses on understanding the significance behind each lesson material, and this process should take place in a joyful learning atmosphere. The approach shift from only discussing concept definitions, to a more contextual, and in-depth learning, promoting critical and innovative thinking by linking concepts to real-world phenomena (Aranditio, 2024). For deep learning to succeed, the entire education system must supports it (Fullan & Langworthy, 2013), including textbooks. Ambiguities within textbooks may hinder students' holistic understanding, while well-structured visual representations bridge the gap between abstract and concrete ideas, reduce cognitive load, and provide deeper comprehension of complex chemical concepts.

Science textbook analysis is not new, and visual materials are a key aspect of their quality. Unfortunately, no published research has examined visual representations and their relation with text in Indonesian chemistry textbooks. This gap is crucial, especialy as Indonesia prioritizes deep learning in 2025. Therefore, this study seeks to address key questions, including what types of visuals are present in Indonesian chemistry textbooks and how these visuals vary across different grade levels. Additionally, it explores how the visuals relate to the textual material and how the degree of connection between visuals, texts, and captions changes as students progress through different grades. This study aims to analyze the types and integration of visual representations in textbooks, aligning them with Indonesia's 2025 deep learning goals. It provides insights for educators to select better textbooks and offers recommendations for publishers to improve visual quality. Ultimately, well-designed visuals can enhance students' engagement with abstract concepts, fostering deeper learning and better alignment with national educational goals.

METHODS

This research is a qualitative research because it explores the characteristics of visuals from learning sources rather than testing certain hypotheses (Creswell, 2014). The theoretical framework is social constructivism which emphasizes how "individuals seek understanding of the world in which they live and work" (Creswell & Poth, 2018, p. 24).

Research design

This research is a document analysis, an organized procedure to review or evaluate documents (Bowen, 2009). The documents analyzed are chemistry textbooks, categorized as public documents widely used in Indonesian schools (Burgess, 1984). Document analysis is suitable for this study because it allows for the examination of both textual and visual materials, providing insights into how visuals are integrated into textbooks (Bowen, 2009).

Sample selection

This study uses purposive sampling method to select textbooks and the chapters for analysis. We chose to analyze textbooks from Erlangga, a prominent publisher (grades X and XII). The 2013 Curriculum was selected, not the latest *Kurikulum Merdeka*, because the 2013 curriculum is still more established and the latest curriculum does not have chemistry subject for grade X. We decided to analyze the first, middle, and last chapters from each book.

Data collection and analysis procedures

The researchers applied qualitative content analysis method to obtain data. It is a replicable method for generating inferences from document by organizing knowledge into categories based on the research questions (Bowen, 2009; Mayring, 2000). Although this method is often used to analyze text, it also can be applied to interpret visuals as part of the document (Papageorgiou et al., 2017).

Table 1. The modification of the rubric

(a) Original rubric

Criterion	Typology for each criterion
C1: Type of representation	i. Macro ii. Submicro iii. Symbolic iv. Multiple v. Hybrid vi. Mixed
C2: Interpretation of surface features	i. Explicit ii. Implicit iii. Ambiguous
C3: Relatedness to text	i. Completely related and linked ii. Completely related and unlinked iii. Partially related and linked iv. Partially related and unlinked v. Unrelated
C4: Existence and properties of a caption	i. Existence of appropriate caption (explicit, brief, comprehensive, providing autonomy) ii. Existence of problematic caption iii. No. caption
C5: Degree of correlation between representation comprising a multiple one	i. Sufficiently linked ii. Insufficiently linked iii. Unlinked

(b) Modified rubric

Criterion	Typology for each criterion
C1: Type of representation	i. Macro ii. Submicro iii. Symbolic iv. Multiple v. Hybrid vi. Mixed
C2: Interpretation of surface features	i. Explicit ii. Implicit iii. Ambiguous
C3:.1 Relatedness to text	i. Completely related and linked ii. Completely related and unlinked iii. Partially related and linked iv. Partially related and unlinked v. Unrelated
C3.2: Level of contiguity with text	i. Distal ii. Facing iii. Proximal iv. Direct
C4: Existence and properties of a caption	i. Existence of appropriate caption (explicit, brief, comprehensive, providing autonomy) ii. Existence of problematic caption iii. No. caption

The researchers adapted the coding rubric by Gkitzia et al. (2011) (Table 1) which relevant with the study's focus on visual representations and their relation to text. They used Johnston's (1993) three representational levels of chemistry phenomena to analyze how the visuals deliver the concepts to students. To modify the rubric, the researchers analyzed the visuals step-by-step based on the research questions, and used the criteria in the rubric as the center of the analysis and made necessary revisions during the analysis (Mayring, 2000).

Subsequently, the modified rubric was used to analyze the visuals of all sample chapters. The analysis was conducted manually, with the researcher coding each visual based on the rubric criteria. Moreover, the results of the analysis from those criteria are organized in a table. After that, quantitative data from each criterion of the visuals were analyzed using basic quantitative analysis. The frequencies of coded criteria were calculated in the form of percentage. The results were then organized into tables, and basic quantitative analysis was performed to calculate the frequencies and percentages of each criterion.

However, the researcher first analyzed the visual forms to obtain a general picture of the visuals, because based on the pilot analysis, not every visual can be analyzed based on all the criteria in the rubric. This step is expected to make the analysis more precise and accurate. The steps of data collection and analysis are illustrated in Figure 2, which is a modified version of Mayring's (2000) qualitative content analysis model. This ensured consistency and transparency in the analysis, allowing for replicability and reliability in the findings.

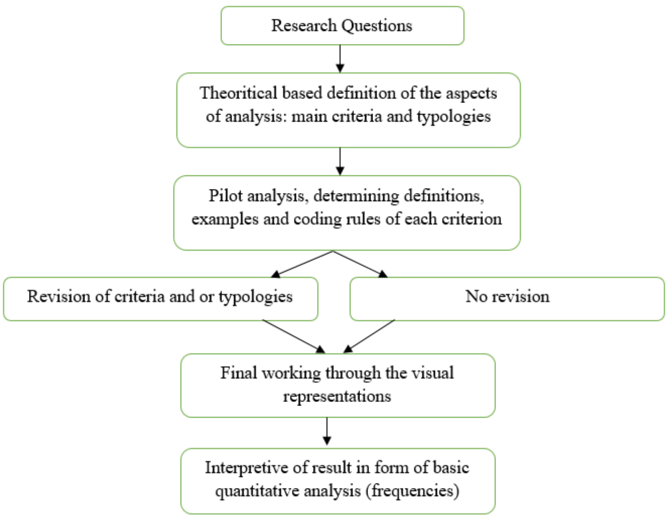


Figure 2. Step model of data collection and analysis procedure modified from(Mayring, 2000)

RESULTS AND DISCUSSION

General Characteristics of Visuals

This research analyzed two Indonesian chemistry textbooks for grade X and grade XII. The two textbooks have different general characteristics. Table 2 summarizes the number of pages, visual representations, and the average number of visuals per page analyzed. The results indicate that the mean of visuals per page between the two textbooks was the same (1.5 visual representations on each page). It indicates that in one page students only need to interact with 1-2 visual representations while reading the content of the related text. Such number is relatively low compared to chemistry textbooks from other countries. For instance, according to (Han & Roth, 2006), Korean and Brazilian textbooks have respectively 2.24 and 1.88 visual representations per page, United States generally had on average 4 visual representations per page (Nyachwaya & Gillaspie, 2016). It raises concerns about whether students are sufficiently exposed to visual aids that could enhance their understanding of abstract concepts.

Table 2. General findings of visual representations in Erlangga chemistry textbooks

Grade	Number of pages sampled	Number of visuals sampled	Average number of visuals per page
X	137	203	1.5
XII	86	130	1.5
Total	223	333	1.5

There were various forms of visual representations analyzed in this work. In chemistry, visual representations are not only in the form of regular images such as photographs or illustrations but also in other forms such as chemical reactions and formulas. It is because chemistry has its own symbol system to represent and visualize its concepts to the learners (Cooper et al., 2017; Kozma & Russell, 2005; Mathewson, 2005).

For the purpose of this study, the researcher used the definitions and forms of visual representations that have been used in similar studies in determining which part of the textbook was included as a visual representation. Eight categories of visual representations were recognized: photograph, illustration, table, diagram, equation, symbol, graphic, and formula. Some of these categories were then divided into a variety of different forms that can be seen in the description part of the table. The most common visual representations were chemical reaction equation and formula.

This research found that the most frequently used forms of visual representations are chemical equations and formulae. This is problematic because such instruction reflects a traditional, formula driven approach to chemistry education, which may prioritize rote learning without conceptual understanding. This imbalance suggests that students are not consistently exposed to visuals that bridge the macroscopic, sub-microscopic, and symbolic levels of chemistry, which are essential for deep understanding (Johnstone, 1993; Kapıcı & Savaşcı-Açıkalın, 2015).

The lack of diversity in visual forms is particularly concerning in the context of Indonesia's 2025 educational goals, which emphasize deep learning and real-world application. Research shows that multi-level representations are crucial for helping students connect abstract concepts to tangible phenomena (Wang et al., 2022). It will be more likely for students to have fragmented knowledge because they are rarely exposed to multiple types of representations (Kapıcı & Savaşcı-Açıkalın, 2015). To align with deep learning objectives, textbooks designer needs to include a variety of visual forms so that problematic visuals will be less dominant. Enhancing the variety and quality of visuals in textbooks will be essential in fostering conceptual understanding and promoting meaningful learning.

The types of visual representations

This section examines the characteristics of visual representations based on the two research questions (Type of representation and Interpretation of surface features).

Table 4. Visual representation types based on category C1 and C2

Criteria	Typology	Grade X (%)	Grade XII (%)	Total (%)
C1: Type of representation	Macroscopic	21.5	7.9	16.2
	Submicroscopic	3.5	1.6	2.8
	Symbolic	62	83.5	70.3
	Multiple	7.5	3.2	5.8
	Hybrid	5.5	3.9	4.9
	Mixed	0	0	0
C2: Interpretation of surface features	Explicit	52.2	60.4	55.5
	Implicit	35.9	38.7	37
	Ambiguous	12	0.9	7.6

Analysis of Representation Types (C1)

Table 4 summarizes the distribution of visual types. Symbolic visual representations were the most prevalent type (70.3%). Then, it is followed by macroscopic visuals with 16.2% which was 53% lower than the symbolic visuals. The next types of visuals had relatively similar proportions: multiple (5.8%) and hybrid (4.9%) while submicroscopic visual representations were the least used type of visuals in the textbooks, with only 2.8%. Interestingly, no mixed representations were found in the visuals analyzed. All visual representations below were taken from the Erlangga textbooks.

The dominance of symbolic visuals is consistent with findings from other Indonesian studies (Addiin et al., 2016; Rahayu, 2014; Shopariah, 2014), but contrasts with international trends. This dominance is caused by the high number of chemical reaction equations and formulae integrated in the textbooks. It is likely related to the teaching and learning style in Indonesian science classes where traditional style such as rote learning remains dominant (Thair & Treagust, 2003; Wangsalegawa, 2009). Symbolic visual representations especially chemical equations and formulae have been proven to be closely related to rote learning in chemistry. This phenomenon is actually common in chemistry teaching (Bunce & Gabel, 2002), because they are symbolic systems created by chemists to replace words to describe chemical phenomena in a simpler way (Hoffmann & Laszlo, 1991) and this type of visual representations may help students to understand the connection between the macroscopic and the sub-microscopic aspects of chemical phenomena (Shehab & BouJaoude, 2016a). However, this imbalance may lead to fragmented knowledge and limit students' ability to develop a holistic understanding of chemistry.

The chemistry textbooks analyzed in this study are less successful in serving as ideal learning resources that build students' complete understanding of chemistry phenomena. Without downplaying the role of symbolic visuals in chemistry, it would be better if the types of visual representations in the textbooks were equally distributed as students need to be exposed to multi-level visuals so that they will be interested and able to translate and relate among various levels of representations (Kapıcı & Savaşcı-Açıkalın, 2015). Depicting one phenomenon with multi-level representations will provide complete understanding and eventually lead to improvement in achievement (Gabel, 1993). It can be inferred that Indonesian students who use the textbooks in this study will be more likely to have fragmented knowledge because they are rarely exposed to multiple types of representations. Chemistry teachers will also struggle because the textbooks do not provide them with adequate variations of visual types. They may have problems teaching students that a chemical phenomenon can be visualized using different levels of representations and linking these different levels to build a complete understanding of chemistry concepts.

The scarcity of macroscopic and sub-microscopic visuals is particularly concerning. It is noteworthy that there is only a small proportion of macroscopic types of visuals in the textbooks when in fact they are significant to build fundamental concepts of chemistry especially those related to tangible concepts in daily life (Johnstone, 2007). It is feared that students who are guided by the textbooks in this study will have a weak foundation on chemistry concepts and less meaningful learning. Another significant finding is that sub-microscopic type of visuals had the least proportion even though they are important to help students have deeper understanding of chemistry concepts at microscopic level (Shehab & BouJaoude, 2016). This may lead to students becoming less familiar with intangible chemistry concepts at sub-micro level. Indonesian chemistry educators need to pay more attention to this because this could be one of the reasons why Indonesian students are having difficulty to deal with abstract science concept as recorded in PISA (OECD, 2023). The lack of macroscopic and sub-microscopic visuals may explain why Indonesian students struggle with abstract concepts, as evidenced by their poor performance in PISA (OECD, 2023). Fig. 4 shows examples of visuals based on the types of representations.

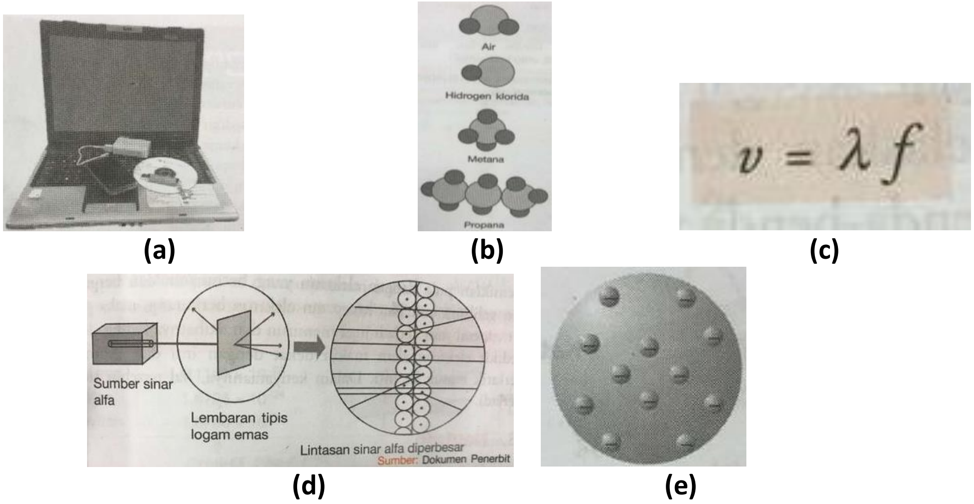


Figure 4. Examples of visuals based on the types of representations (C1).

(a) Macroscopic visual representation.
(b) Submicroscopic visual representation.
(c) Symbolic visual representation
(d) Multiple visual representation.
(e) Hybrid visual representation.

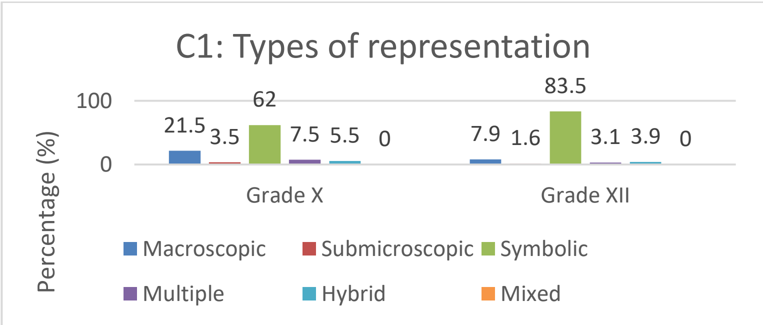


Figure 5. Distribution of types of representation (C1) based on grades

Fig. 5 illustrates the proportion of visual representation types by grade. It shows that symbolic visuals were the most common visual types found in both grades especially in the grade XII book with 83.5% (21.5% higher than in the grade X book). It is an expected result since the students at the higher grade have learned more symbols and formulae so that they have become more familiar in using symbolic visuals. Another predicted outcome is the declining number of macroscopic visuals in the higher grade (in the grade XII was 13.6% lower). It is related to the role of macroscopic visuals, to visualize fundamental concepts of chemistry and catch students' attention- often needed in the initial learning stage or in the lower grade (Harrison & Treagust, 2003). However, the decline in macroscopic visuals in grade XII is also problematic, as these visuals are essential for increasing students' engagement, which is also crucial for the highest grade in high school as they will face high-stake examinations that includes high pressure.

In relation to Fig. 5, the proportion of submicroscopic visuals was surprisingly very low in grades XII (1.6%), less than half of that in the grade X (3.5%). It is unusual since submicroscopic visuals depict chemistry phenomena at the micro level which is complex and abstract, and this type of visuals is more appropriate for higher grade students (Johnstone, 2007).

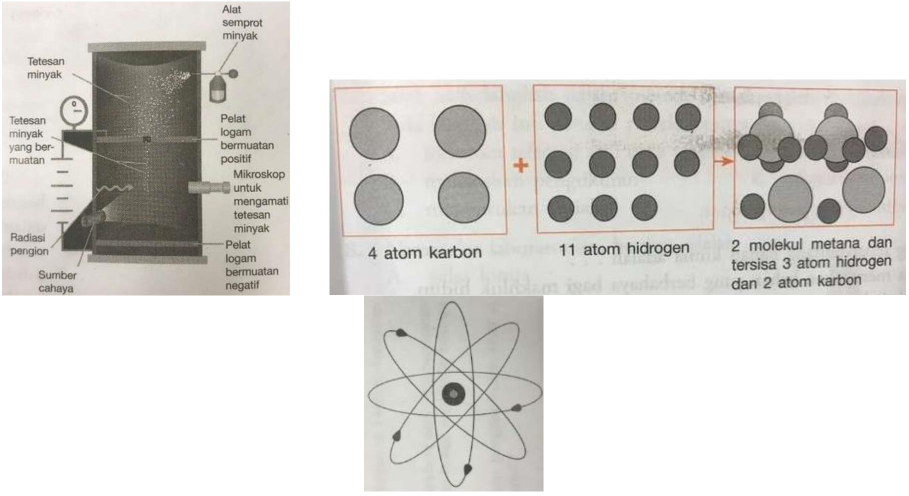
Moreover, the limited use of multi-level representations (multiple and hybrid) in the textbooks is concerning, particularly given their potential to enhance conceptual understanding. Surprisingly, the number of visuals with more than one level of representation (multiple and hybrid) was actually higher in the grade X (13%) than that in the grade XII (7%). This is contrary to the expectations of some researchers (Corradi et al., 2012; Kapıcı & Savaşcı-Açıkalın, 2015). They contend that students at the higher grades should be better at connecting the chemistry concepts between levels than those at the lower grades. If viewed from a different perspective, the possible reason for this phenomenon is more likely because the material in grade X material is less challenging and less complex than that in grade XII so that the grade X chemistry textbooks contain more multi-level of visual representations. However, this approach risks underpreparing students for the abstract and challenging concepts they will encounter in higher grades.

Treagust (2007) stated that although different types of representations can facilitate comprehensive chemistry knowledge, the simultaneous presentation of different types of representations cannot be used in teaching difficult science concepts because students can be overwhelmed. This suggests that textbook designers must strike a careful balance: incorporating multi-level visuals to build foundational understanding in lower grades, while gradually increasing their complexity to align with students' cognitive development. The current imbalance in visual representation types may hinder students' ability to transition smoothly from concrete to abstract thinking, ultimately limiting their mastery of chemistry concepts

Interpretation of surface features (C2)

The first research question (the types of the visuals) can also be answered using the rubric second criterion, i.e. interpretation of the surface features (C2). Table 4 shows that more than half of the visuals (55.5%) are explicit visual representations, meaning that the textbooks are dominated by visuals which clearly illustrate the meaning of their individual components. For example, Fig. 6a illustrates the Millikan oil drop experiment and each component of the apparatus and experiments is mentioned clearly. This clarity is essential for helping students decode complex visuals and connect them to the underlying concepts (Gkitzia et al., 2011).

Unfortunately, there is still a fair amount of visuals that are implicit (37%) or even totally ambiguous (7.6%). It indicates that there are visuals in the textbooks that can be classified as questionable, as they may not help learners understand the meaning of all the components and understand the correct message behind the visuals. These types of visuals can potentially lead to students' misconception and even underestimation because they are seen only as decorations (Gkitzia et al., 2011). It indicates that the textbook designers overlook the significance of this feature. Despite the prevalent ambiguity about the meaning of visual components (e.g., Gkitzia et al., 2011; Shehab & BouJaoude, 2016), all visuals in the textbooks should have clear and explicit features.



(a) Explicit visual visual **(b)** Implicit visual **(c)** Ambiguous

Figure 6. Examples of visuals based on the surface features (C2).

Fig. 7 illustrates the proportion of visual representation types based on their interpretation of surface features in the textbooks with respect to the grade levels. It is shown that explicit visuals were the most common visual types found in both grades. It is interesting that the proportion of explicit visuals rose from 52.2% in grade X to 60.4% in grade XII. On the other hand, the percentages of implicit visuals were similar in grade X (35.8%) and XII (38.7%). These findings are anomalous because students in the higher grade are more likely to have superior prior knowledge about chemistry since they have been taught and exposed to the subject in the lower grade whereas those in the lower grade have just started learning chemistry and thus need clearer and more explicit visuals that will facilitate their learning of chemistry concepts at the initial stage. It can be argued that the textbooks in the lower grade may cause more issues than those in the higher grade.

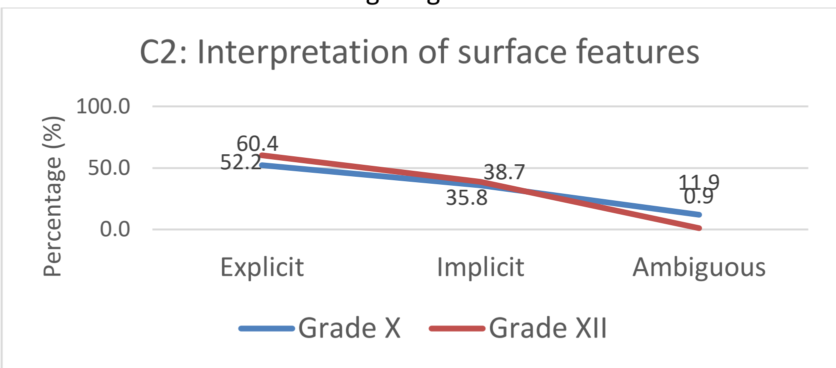


Figure 7. Distribution of visuals based on category C2 with respect to grades.

This misalignment between visual clarity and students' prior knowledge highlights a critical flaw in textbook design. Visuals are most effective when they align with students' cognitive abilities and prior knowledge (Gkitzia et al., 2011). The current imbalance may increase learning difficulties, particularly for students in lower grades, who rely heavily on clear and explicit visuals to navigate unfamiliar concepts. To address this, textbook designers must prioritize clarity and ensure that visuals are appropriately tailored to students' developmental stages.

Table 5. Summary of visuals relation with text based on category C3.1, C3.2 and C4

Criteria	Typology	Grade X (%)	Grade XII (%)	Total (%)
C3.1: Relatedness to text	Completely related and linked	45.4	37.4	42.4
	Completely related and unlinked	41.3	51.2	45.3
	Partially related and linked	2.6	1.7	2.3
	Partially related and unlinked	7.1	7	7.1
	Unrelated	3.4	1.7	2.9
C3.2: Level of contiguity with text	Distal	15.3	4.7	6.3
	Facing	5.9	6.2	6
	Proximal	0	0	0
	Direct	78.8	89.2	87.7
C4: Existence and properties of a caption	Appropriate caption	42.2	47.8	44.3
	Problematic caption	11.5	2.6	8.1
	No caption	46.4	49.6	47.6

Relatedness to text (C3.1)

The second research question — how the visuals used in Indonesian chemistry textbooks relate to the main texts and captions and how they change according to grades — can be answered using the third criteria in the rubric, i.e. relatedness to text (C3.1) and level of contiguity with text (C3.2).

It can be seen from Table 5 that almost all visual representations (87.8%) in the two chemistry textbooks were completely related to the text either linked (42.4%) or unlinked (45.3%). This high level of relatedness will be beneficial for students as it allow students to interpret the message of the visuals more easily when they are accompanied by compatible text (Mayer, 2002). For example, Fig. 8a shows chemicals products in daily life, which is completely related to the text that discusses the role of chemistry in everyday life. However, the fact that more visuals are unlinked than linked suggests a missed opportunity to reinforce learning. Unlinked visuals, even if related, require students to independently connect them to the text, which can be challenging, especially for those with limited prior knowledge (Gkitzia et al., 2011).

Unfortunately, despite the high proportion of related visuals, several visual representations are partially related (9.4%) or even unrelated (2.9%) to the content of the text. Fig. 8b is an example of partially related visuals about weighing of rice and granulated sugar using mass unit, but the text only mentions the weighing of sugar, force students to infer connections on their own. This can lead to confusion or misinterpretation, particularly for novice learners. Fig. 8c is an example of unrelated visuals. It shows symbol of hazardous chemicals and while the text discusses the characteristics of chemicals, it does not mention at all about the symbolization of hazardous chemicals. Such visuals not only fail to support learning but may also distract or mislead students, undermining the effectiveness of the textbook (Shehab & BouJaoude, 2016).

The distribution of relatedness varies by grade. The number of completely related and linked visuals was higher in the grade X (45.4%), which is an expected result since the relation between visuals and text should be the clearest in the lower grades especially when chemistry subject is firstly introduced. Students are expected to be able to face more challenging task at the higher grade (grade XII) as they should have more competence. This is consistent with the finding in this study where completely related and unlinked visuals are more prevalent in the grade XII (increased by 10.9%). While this may be true to some extent, it risks leaving weaker students behind. Unexpectedly, a higher number of unrelated visuals was found in the lower grade (grade X). It means that the lower grade students are more likely to face difficulties as they fail to see the connection between some visuals and their respective text. It may inhibit them from making correct interpretation and cause misconceptions in learning the chemistry concepts (Shehab & BouJaoude, 2016).

(a) (b) (c)

Figure 8. Examples of visuals based on their relatedness to text (C3.1).

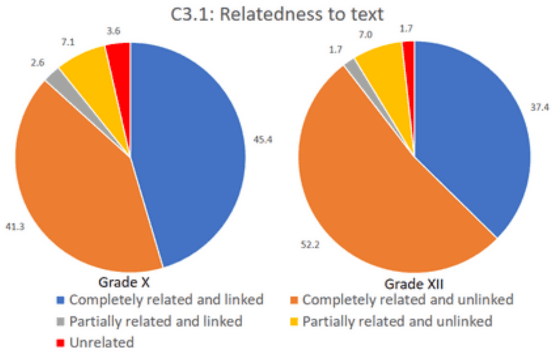


Figure 9. Distribution of visuals based on category C3.1 with respect to the grades.

Level of contiguity with text (C3.2)

In addition to the relatedness of visuals to the text, according to Mayer's (2002) contiguity principle, the physical integration of visuals and text is a crucial fator in effective learning and need to be analyzed. This principle emphasizes that learning is enhanced when corresponding visuals and text are presented close to each other, reducing the cognitive effort required to integrate information. This aspect will be examined using the rubric of the next criterion- level of contiguity with text (C3.2). In Table 5, the result shows that almost all of the visual representations (87.7%) were the direct type. It indicates that almost 9 out of 10 visuals were located closer than a half page from the instructional guidance/most relevant text. This contiguity benefits students because when they try to understand the visuals, they often need to repeatedly switch between visuals and the text (Slough et al., 2010). If the visuals are positioned close to the text, students may understand the information more smoothly. For example, when students encounter a visual depicting a chemical reaction, having the explanatory text nearby helps them quickly connect the visual to the concept being discussed, enhancing their understanding.

Several observations can be made from Fig. 10 about the level of contiguity of visuals with text based on the grades. Generally, there is no significant difference on the visuals' level of contiguity with text between the two grades. However, if closely examined, the number of visuals that are contiguous with text is slightly higher in the upper grade (89.1%) than in the lower grade (86.7%). It is surprising because visuals for the lower grades need to be more contiguous, or using a simpler organization. Students from the lower grades are less experienced and have weaker prior knowledge, would benefit more from closer integration of visuals and text.

The slight increase in contiguity for grade XII may reflect an assumption that higher-grade students can handle greater spatial separation, but this risks disadvantaging students who still rely on clear, immediate connections between visuals and text. This misalignment between visual contiguity and students' cognitive needs highlights a critical flaw in textbook design. The findings underscore the importance of spatial contiguity in supporting effective learning. While the majority of visuals are well-integrated, the presence of distal and facing visuals, particularly in lower-grade materials, undermines their effectiveness. Textbook designers must prioritize spatial contiguity, especially for novice learners, to minimize cognitive load and enhance comprehension.

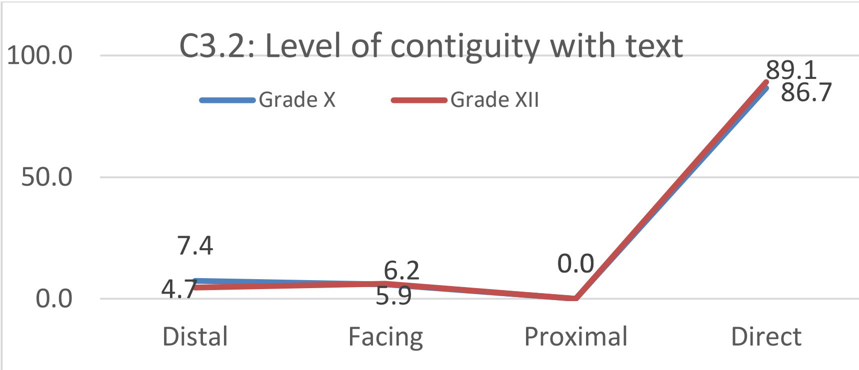


Figure 10. Distribution of visuals based on category C3.2 with respect to the grade

Existence and properties of a caption (C4)

Another criterion related to the second research question in this study is the existence and properties of the caption (C4), which play a vital role in clarifying the meaning of visuals. This is significant because the caption is part of the text material that is most closely related to visuals. The caption should guides students' interpretation of visuals, especially when the visuals are not directly integrated into the text.

According to Table 5, almost half of the visual representations (47.6%) had no caption although most of them are equations (mathematical and chemical) and formulae that are incorporated with text. This type of visual representations does not need a caption as they are read as part of the text. Nevertheless, if examined closely, there are still many without-caption visuals which are not integrated to the text, leaving students to interpret them independently. This is problematic, as visuals without clear captions can lead to multiple interpretations or misunderstandings, particularly for students with limited prior knowledge (Gkitzia et al., 2011; Pozzer-Ardenghi & Roth, 2005).

It is also noteworthy that in Fig 11, visuals in the lower grade textbooks (11.5% in grade X) contained more visuals with problematic or even no caption and fewer appropriate captions compared to the higher grade textbooks (2.6% in grade XII). It is an unexpected result because grade X is the first grade where students learn chemistry in school. Kapıcı & Savaşcı-Açıkalın (2015) contend that caption will be very helpful to support learning unfamiliar concepts, and without an appropriate caption, the message can be misinterpreted by the novice learners. It shows that the textbook designers neglect the important role of instructional guidance for visuals and its relation with students' level of learning.

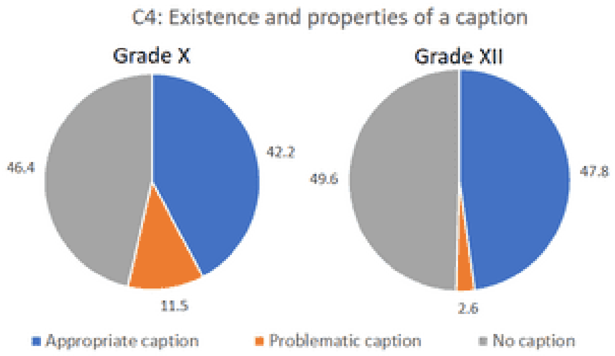


Figure 11. Distribution of visuals based on category C4 with respect to the grades.

In sum, the analysis of visual representations in Indonesian chemistry textbooks reveals both strengths and areas for improvement. The number of visual representations per page in the textbooks is appropriate to prevent students from being overwhelmed with its proportion. However, the visuals are heavily dominated by chemical equations and formulae, included as symbolic type. Such an imbalance undermines the development of a holistic understanding of chemistry, which is essential for deep learning. Based on the criterion of surface features interpretation, most of the visuals are categorized as explicit so students could easily understand the meaning of each visual component. In addition, related to the visuals' relation with text material, most of them are completely related with the content but not directly referred to in the text. It can lead to students not paying adequate attention to these visual representations because they cannot understand the correlation with the text or simply skip and only read the visuals that are explicitly referred to in the text. Positively, most of these visuals are contiguous with the related text and categorized as either with-caption or incorporated into text (thus, no caption is required) which is helpful to understand the message of the visuals. With respect to the grade, it can be said that the textbook authors do not pay adequate attention to students' level of competence when integrating the visuals into the books as more problematic characteristics are found in the lower grade than in the upper grade for some criteria. Related to the types, it is found that the number of multi-level representations and sub-microscopic visuals, which are notably more complex and abstract, is unexpectedly higher in the lower grade. Moreover, the upper grade textbooks actually contain more explicit and clear types of visuals. Based on visuals' relation with text material, it was found that lower grade textbooks contain visuals that are either unrelated to the content, lack captions, or are placed far from the corresponding text. This fact may inhibit the novice learners from making correct interpretation and cause misconceptions in learning the chemistry concepts. As Indonesia aims to prioritize deep learning in 2025, improving the design of textbooks to integrate more diverse and multi-level visual representations will be crucial in fostering a deeper and more meaningful understanding of chemistry concepts.

CONCLUSION

This study examined the types and textual integration of visual representations in Indonesian chemistry textbooks through qualitative content analysis. Results show a predominance of symbolic visuals with limited multi-level representations, and a lack of clear textual references, which may hinder students' conceptual understanding. These issues are more pronounced in lower-grade textbooks, potentially affecting students' ability to achieve deep learning as targeted in Indonesia's 2025 education goals. To improve textbook effectiveness, authors should incorporate more varied and integrated visual types, especially multi-level representations to support conceptual learning and real-life application. Teachers and schools also need to be more critical in selecting and using textbooks, while systemic support is needed to regularly review textbook quality. This study is limited by its sample scope (two textbooks from one publisher). Future research should explore other publishers, subjects, and how students and teachers interact with visuals, to better align textbook design with the principles of deep learning and Indonesia's broader educational transformation agenda.

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