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Analysis of Merdeka Curriculum Chemistry Textbooks on Atomic Structure Based on Multirepresentation of Chemistry

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A B S T R A C T

Atomic structure is a basic topic in chemistry learning that is very important as a foundation for other materials. Understanding this concept requires representations that are able to describe abstract concepts more concretely, with textbooks acting as the main learning resource. Textbooks help learners understand abstract concepts through various forms of representation. However, the chemistry textbooks of the Merdeka Curriculum still show shortcomings, such as the use of inappropriate representations and sourced from the internet. This study analyzes how the representation in the two Merdeka Curriculum chemistry textbooks used in SMA/MA Padang city, with an analysis based on Gkitzia's criteria. The results of this study indicate that chemistry textbooks A and B are dominated by 44% sub-microscopic and 36% macroscopic aspects (C1), in books A and B the surface features of the representations are generally explicit (C2), the representations of books A and B show that they are completely related and linked to the text (C3), in book A the no caption of the representation, while in book B the are existence of problematic caption (C4), books A and B the degree of correlation between representations comprising a multiple one is generally insufficiently linked (C5).

1. Introduction

Education in Indonesia continues to undergo changes to improve the quality of learning. One of these efforts is through the implementation of the Merdeka Curriculum, which provides flexibility for learners to explore material according to their interests and talents (Fauzi, 2022). This curriculum aims to encourage independence, improve critical thinking skills, and student creativity through a more meaningful learning approach (Cholilah et al., 2023); (Mulyasa, 2023). The Merdeka curriculum also provides freedom for teachers and schools to customize learning to the needs of learners (Wahyudin et al., 2024). One of the important elements in implementing the Merdeka curriculum is textbooks (Ginting et al., 2023). In its implementation, textbooks play an important role as the main source of learning. Textbooks must be able to present relevant, interesting, and easy-to-

understand material needed by students and teachers in the learning process (Wulandari et al., 2019).

The textbooks used must be in accordance with learning objectives, methods, and student characteristics, and be in line with the demands of the Merdeka Curriculum (Ginting et al., 2023). Textbooks to meet standards need to be appropriately designed, meet curriculum requirements, and have conceptual validity to ensure the accuracy of the material (Gilbert and Treagust, 2009). In chemistry learning, textbooks play a strategic role to help learners understand abstract concepts such as atomic structure. Textbooks must present the material in an interesting and easy-to-understand manner for students (Luthfiana et al., 2019). These textbooks must be able to provide accurate information to support effective learning (Gkitzia et al., 2011). Chemistry is a complex field of science, with abstract material that often makes it difficult for students to understand (Sandi, 2019); (Pratiwi et al., 2020). One of the abstract chemistry materials is atomic structure, which is the basis for other chemistry topics (Zollman, 1999).

The relationship between concepts in atomic structure requires a deep understanding to support the success of further chemistry learning (Pratiwi et al., 2020). To support the learning of atomic structure material, textbooks must be able to present various representations comprehensively. Multirepresentation is an approach that integrates various forms of representation, such as descriptive text, diagrams, tables, and graphs, to make it easier for students to understand abstract concepts (Gilbert and Treagust, 2009). This approach helps students develop chemical literacy skills, namely the ability to interpret and use various chemical representations in understanding phenomena (Nopriadi et al., 2022). tomic structure material, which is fundamental and complex, is often a challenge for learners because it requires the ability to connect various representations, including text, images, graphs, and diagrams (Pratiwi et al., 2020). lack of understanding of this concept can hinder students in understanding other interconnected chemical materials (Zollman, 1999); (Sukmawati, 2019). One approach to facilitate students' understanding of chemical materials is through multirepresentation. This approach uses various forms of representation such as macroscopic, sub-microscopic, and symbolic to help learners understand abstract concepts more thoroughly (Gilbert and Treagust, 2009). However, research shows that the chemical literacy of students in Indonesia is still low, with an average score of only 58.38% (Nopriadi et al., 2022). One of the causes is the lack of learners' ability to connect different chemical representations, especially in the context of learning atomic structure. This emphasizes the importance of multirepresentation-based chemistry textbooks to improve student understanding (Gilbert and Treagust, 2009).

Observation of chemistry textbooks based on the Merdeka Curriculum shows that most schools use similar books, with many visual representations sourced from *shutterstock.com*, which are less verified than standard references. This condition emphasizes the need to evaluate chemistry textbooks to support learning effectively. Previous research conducted by Pratiwi et al., (2020) found that multirepresentations in the 2013 Curriculum chemistry textbooks mostly met the

criteria of Gkitzia et al., (2011). However, a similar study has not been conducted for the Merdeka Curriculum, especially on atomic structure material. This study aims to evaluate the fulfillment of multirepresentation criteria in these textbooks that are needed to support students' understanding, provide recommendations for the development of more effective textbooks, and help teachers choose books with appropriate representations for optimal learning.

2. Methodology

Research on multirepresentation in the chemistry textbooks of the Merdeka Curriculum aims to evaluate the extent to which the book presents various types of representations that support understanding of the concept of atomic structure. This evaluation includes analyzing the quality and number of representations available, their relevance to the concepts taught, and their relationship to the learning context according to the objectives of the Merdeka Curriculum. The research data comes from the chemistry textbooks of SMA/MA Merdeka Curriculum in Padang. The research was conducted in three stages: (1) Selection and sampling, starting with observations to schools, followed by the selection of two chemistry textbooks used in schools for analysis; (2) Coding and analysis using the Gkitzia et al., (2011). conducted by five coders, consisting of two other researchers, two lecturers, and the main researcher; and (3) Concluding the results of the analysis, by comparing the two textbooks with the seventh edition of Brady's standard book. The research instruments included the Multirepresentation Analysis Sheet and Reliability Sheet, while the data analysis technique used the reliability test with the Krippendorff Alpha formula (Neuendorf, 2002).

$$\boldsymbol{\alpha = 1 - \frac{D_o}{D_e}}$$

Notes: α = Krippendorff Alpha Coefficient, Do = Observed disagreement, De = Expected disagreement.

The method or criteria that will be used to analyze chemical representations and relationships between representations is the method proposed by Gkitzia et al., (2011), each criterion consists of several typologies presented in table 1.

Table 1. Criteria for the Evaluation of Chemical Representations and Their Characteristics

Criteria		Typology for Each Criteria	
C1	Type of representation	i.	Macroscopic
		ii.	Sub-microscopic
		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 representations comprising a multiple one	i.	Sufficiently linked
		ii.	Insufficiently linked
		iii.	Unlinked

Source: Gkitzia et al., (2011)

The criteria for chemical representation and its typology are described as follows.

Type of representation (C1): The first criterion relates to the different forms of representation featured in school textbooks. Representing science through three levels of multirepresentation is an important aspect to support the understanding of the theory. There are six typologies for this first criterion, namely macroscopic, sub-microscopic, symbolic, multiple, hybrid and mixed. Representation is categorized as hybrid when it combines elements from two levels of representation, while multiple representation shows chemical phenomena on more than one level of representation simultaneously. Mixed representation refers to the use of one of the three levels of representation along with other types of representation, such as analogy.

Interpretation of surface features (C2): This second criterion is to determine the extent to which surface features in a representation are clearly labeled. Surface features refer to the characteristics or elements that make up a representation. This second criterion includes three typologies: explicit, implicit, and ambiguous. A representation is categorized as explicit if the interpretation and meaning of its surface features are clearly explained in the text. Conversely, if the meaning of surface features is not explained in detail, it is categorized as implicit. Meanwhile, representations that give no clue at all about the meaning of their surface features are classified as ambiguous.

Relatedness to text (C3): The third criterion assesses how a representation is consistent and connected to the content of the text, and whether there is a direct relationship between the text and the representation. To classify these representations, five typologies were used, namely: (i) Completely related and linked, (ii) Completely related and unlinked, (iii) Partially related and linked, (iv) Partially related and unlinked, and (v) Unrelated. A chemical representation is categorized as completely related if it precisely describes the content of the text. In contrast, if they only described a similar subject but not exactly the same, they were coded as partially related. Representations that are completely unrelated to the content of the text will be labeled as unrelated. In addition, representations can also be coded as linked or unlinked, depending on whether the text refers directly

to the representation, for example through phrases such as “as shown in Figure” or without a direct reference.

Existence and properties of a caption (C4): The fourth criterion has an important role in clarifying the content and message conveyed by a representation. In addition, appropriate explanations can support the ease of learning through books. A good description should be clear, concise, thorough and self-contained. This fourth criterion includes typologies, namely: Existence of appropriate caption (Explicit, brief, comprehensive, providing autonomy), existence of problematic caption, and no caption.

Degree of correlation between representations comprising a multiple one (C5): This fifth criterion addresses the interrelationship between multiple representations that are clearly conveyed. This analysis focuses on the first criterion (C1) with a multiple typology. There are three categories in this criterion: Sufficiently linked, insufficiently linked and unlinked. Multiple representations are classified as sufficiently linked if the relationship between their components is obvious through the equivalence of surface features. In contrast, a multiple representation is categorized as insufficiently linked if the equivalence is only apparent in a few clearly indicated surface features.

3. Results and Discussion

This research is a description of the multirepresentation analysis in the Merdeka Curriculum chemistry textbooks on atomic structure material, using the representation rubric developed by Gkitzia et al., (2011) with five criteria, namely C1 to C5. The analysis was carried out on three chemistry textbooks: the standard book (Brady), as well as book A and book B of the Merdeka Curriculum. Prior to the analysis, the representations in the textbooks were coded by five coders, consisting of two other researchers, two lecturers, and the main researcher. This research also includes intra-rater and inter-rater reliability testing based on the coding results that have been carried out by the coders. The following are the results of the reliability test for the standard book, book A, and book B on atomic structure material.

1) Reliability Test

Reliability refers to the consistency of the same measurement results and the suitability of scores between coders (Sanaky et al., 2021). The reliability test aims to ensure the stability of the analysis between coders, so that the analysis data can be used with more confidence (Creswell, 2014). In this study, the reliability test was carried out through coding and multirepresentation analysis using the chemical representation criteria from Gkitzia et al., (2011), and measured using Krippendorf Alpha. The inter-rater reliability results are presented in table 2.

Table 2. Inter-Rater Reliability Results

Criteria	Criteria Type	Reliability Value	Reliability Description
C1	Type of representation	0,96	Strong
C2	Interpretation of surface features	0,977	Strong
C3	Relatedness to text	0,985	Strong
C4	Existence and properties of a caption	0,985	Strong
C5	Degree of correlation between representations comprising a multiple one	0,76	Moderate

The results of the inter-rater reliability test on multirepresentation coding and analysis showed a strong category for criteria C1-C4 ($\alpha > 0.8$) and a moderate category for criteria C5 ($0.67 \leq \alpha < 0.8$), so the analysis is considered reliable. This is in accordance with the statement of Sanaky et al., (2021) which states that reliable test results indicate that the results of the analysis in the study do not provide results that vary significantly. The intra-rater test conducted by researchers within an interval of two weeks also showed high reliability (strong category) with consistent results for the three books analyzed. This is in accordance with the statement of Sanaky et al., (2021) hich states that reliable research results show that the data obtained are consistent when measurements are taken repeatedly or in different time periods.

2) Multirepresentation Coding and Analysis of Chemistry Textbooks

In the Brady chemistry textbook used as a standard book in this study, 35 representations were obtained which will be coded and analyzed for multirepresentation. In chemistry textbook A of the merdeka curriculum, 16 representations are obtained which will be coded and multirepresentation analysis. In chemistry textbook B, the merdeka curriculum obtained 11 representations that will be coded and analyzed for multirepresentation. The number of images to be coded and analyzed for multirepresentation is 62 representations. Chemical representation can be seen from the criteria for the C1-C5, each of these criteria has a different typology. Images with chemical representations were analyzed with the 1st to 4th criteria (C1 to C4). However, in the type of representation (C1) with typology Multiple, chemical representation will be analyzed using the 1st to 5th criteria (C1 to C5). The results of the analysis of the representation of chemistry textbooks contained in the standard book, book A, and book B based on the agreement obtained from five coders are presented in table 3.

The first criterion (C1) focuses on identifying and analyzing the types of chemical representations for each textbook on atomic structure material. In chemistry textbook A, the merdeka curriculum shows the results that this textbook already contains four types of representations including i) Macroscopic, ii) Sub-microscopic, iii) Symbolic, and iv) Multiple, which is dominated by ii) Sub-microscopic with a percentage of 44%.

Table 3. Data from the Analysis of Chemical Representation Based on Gkitzia's Criteria and Typology in Three Chemistry Textbooks

Criteria and Typology		Standard Book	Percentage	Book A	Percentage	Book B	Percentage
C1	i	12	34%	4	25%	4	36%
	ii	10	29%	7	44%	3	27%
	iii	7	20%	2	13%	2	18%
	iv	4	11%	3	19%	1	9%
	v	2	6%	0	0%	1	9%
	vi	0	0%	0	0%	0	0%
C2	i	7	20%	9	56%	9	82%
	ii	8	23%	2	13%	1	9%
	iii	20	57%	5	31%	1	9%
C3	i	27	77%	9	56%	10	91%
	ii	8	23%	2	13%	1	9%
	iii	0	0%	2	13%	0	0%
	iv	0	0%	2	13%	0	0%
	v	0	0%	1	6%	0	0%
C4	i	26	74%	2	13%	3	27%
	ii	1	3%	2	13%	7	64%
	iii	8	23%	12	75%	1	9%
C5	i	3	75%	0	0%	0	0%
	ii	1	25%	2	67%	1	100%
	iii	0	0%	1	33%	0	0%

Criteria (C1) Type of Representation

In chemistry textbook B, the merdeka curriculum shows the results that this textbook already contains five types of representation including i) Macroscopic, ii) Sub-microscopic, iii) Symbolic, iv) Multiple, and v) hybrid which is dominated by i) Macroscopic with a percentage of 36%. In book A the number of symbolic and multiple representations is quite low and there are no hybrid and mixed representations, while in book B the number of multiple and hybrid representations is quite low and there are no mixed representations. Representation example in figure 1.

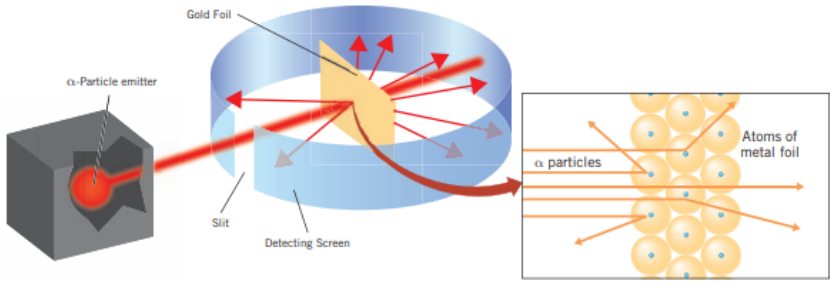
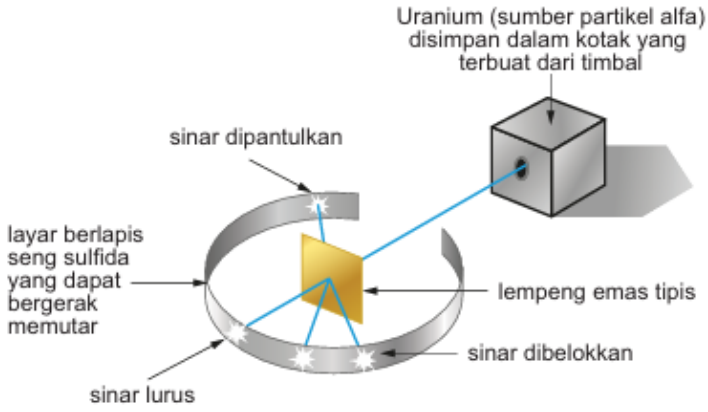


Figure 0.7 | **Some alpha particles are deflected by a thin gold foil.** Some hit something very massive head-on and are deflected backward. Most sail through. Some, making near misses with the massive "cores" (nuclei), are still deflected, because alpha particles have the same kind of charge (+) as these cores.

(a)



Gambar 1.7 Percobaan Rutherford

(b)

Figure 1. (a) Multiple Representation Types (Macroscopic and Sub-Microscopic) in the Standard Book, (b) Macroscopic Representation Types in Book B

Figure 1 (b) is an image from book B with Macroscopic representation and figure 1 (a) is an image from the standard book used as a guide to see the representation on the discussion of the same concept, namely about the concept of Rutheford's experiment depicted in macroscopic form. The Rutherford experiment is a chemical experiment that can be observed directly in the direction of the resulting light. But to understand the results of the experiment more clearly on how the direction of the rays can be forwarded, deflected, reflected, it is necessary to explain in sub-microscopic form. The sub-microscopic level can explain the type that describes the particulate properties of matter, which is the basis for interpretation and understanding of chemical phenomena (Gkitzia et al., 2011). In book B there are concepts that should be added referring to the standard book to clarify the meaning of the representation of Rutherford's experiment so that students can better know and understand how a clearer picture of the experiment conducted by Rutherford. In the sub-microscopic representation it can be seen that alpha rays are forwarded because they do not hit positively charged nuclei, indicating that most of the atom is empty space. Alpha rays are deflected when approaching positively charged nuclei so that there is a repulsive force between them that causes alpha rays to be deflected, and reflected when they collide directly with dense nuclei so that the rays are reflected back towards their source (Jespersen et al., 2014). Learners can form a deeper understanding of the underlying concepts if supported by appropriate representations, apart from that the three aspects of representation can be presented simultaneously on the correct concept in chemistry textbooks (Gkitzia et al., 2011).

Criteria (C2) Interpretation of Surface Features

The second criterion (C2) focuses on the extent to which surface features in a representation are clearly labeled or described for each textbook on atomic

structure material. Surface features refer to the characteristics or elements that make up a representation. In chemistry textbook A and chemistry textbook B, the Merdeka curriculum shows the results that these two textbooks already contain three representations including i) Explicit, ii) Implicit, and iii) Ambiguous which is dominated by i) Explicit 56% in chemistry textbook A, and 82% in chemistry textbook B. Representation example in figure 2.

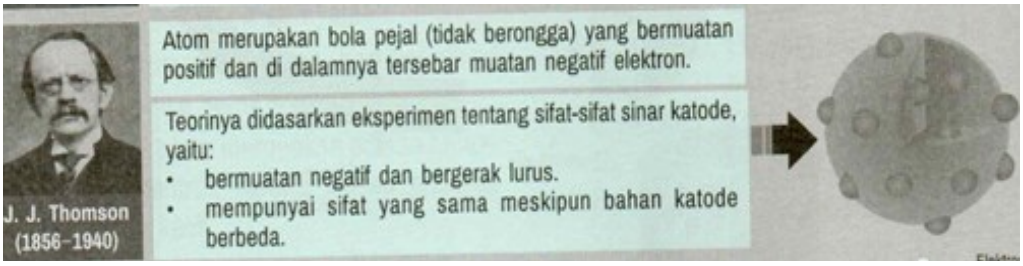
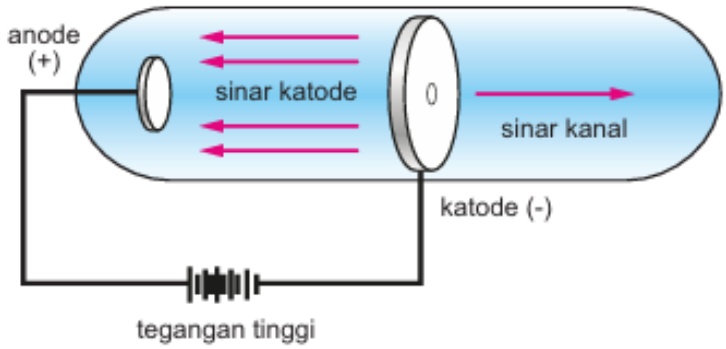


Figure 2. Interpretation of Surface Features of Ambiguous Images in Book A

Figure 2 is an example of representation with ambiguous typology in chemistry textbook A contained in the concept of Thomson's atomic model material. In chemistry textbook A, the concept is categorized as ambiguous typology because there is no information labeling the surface features of the image on the representation, which does not show which electrons are negatively charged, which are positively charged and which are hollow spaces. This is what often makes students wrong in interpreting the concept of material. Explicit representation of surface features is when the representation is clearly labeled which electrons are negatively charged, which are positively charged and which are hollow spaces. Gkitzia et al., (2011) stated that the meaning of the representation features must be clearly labeled to increase the likelihood that learners will understand the content of the concept well. Clear labeling of each element is needed in chemical representations because it can help learners in understanding the concept of atomic structure.

Criteria (C3) Relatedness to Text

The third criterion (C3) has the purpose of assessing how a representation is consistent and connected to the content of the text, and whether there is a direct relationship between the text and the representation. The chemistry textbook A of the Merdeka curriculum shows the results that this textbook already contains five representations including i) Completely related and linked, (ii) Completely related and unlinked, (iii) Partially related and linked, (iv) Partially related and unlinked, and (v) Unrelated which is dominated by i) Completely related and linked 56%. Chemistry textbook B shows the results that this textbook already contains two representations including including i) Completely related and linked, (ii) Completely related and unlinked which is dominated by i) Completely related and linked 91%. Representation example in figure 3.



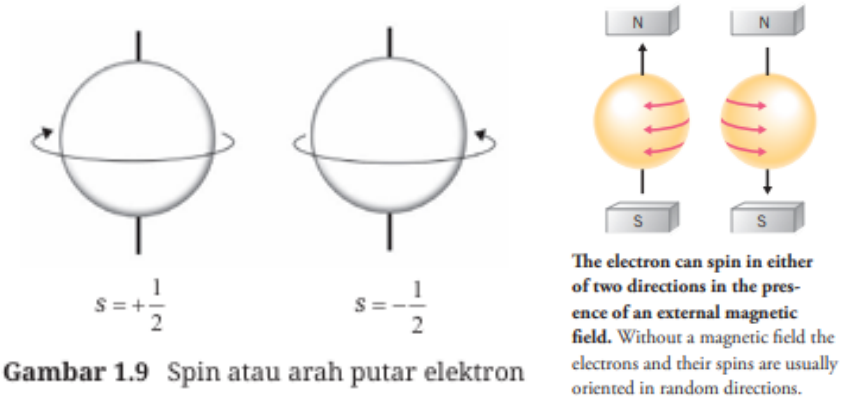
Gambar 1.6 Aliran sinar katode dan sinar kanal

Figure 3. The Relatedness to Text of the Typological Representation is Completely Related and Linked in Book B

The representation text in Figure 3 has explained and described well and clearly the concept of the flow of cathode rays and the same channel rays as the represented image so that it can be said that between the text and the representation image has a connection called completely related. Apart from that, Figure 3 has also shown that the representation has a relationship with the text that refers to it directly, namely by mentioning the words *as shown in Figure 1.6* in the text explaining the representation, so it can be said that between the text and the representation image has a text relationship that refers directly to the image which is called linked. With a direct link in the text, learners can more easily understand the relationship between the text explained and the image presented. According to Gkitzia et al., (2011) learners have a tendency to read only the necessary information and tend to glance at the images without giving the necessary attention. Therefore, textbook authors should ensure the representations are linked to the text so that learners understand the images, the concepts being explained, and the relationship between them.

Criteria (C4) Existence and Properties of a Caption

The fourth criterion (C4) aims to examine the existence and properties of the caption of chemical representation images for each textbook. The two textbooks analyzed show that in chemistry textbook A and chemistry textbook B analyzed show the results that these two textbooks already contain three representations including i) Existence of appropriate caption (Explicit, brief, comprehensive, providing autonomy), ii) existence of problematic caption, and iii) no caption, where in chemistry textbook A which is dominated by typology iii) no caption 75%, and in chemistry textbook B which is dominated by typology ii) existence of problematic caption 64%. Representation example in figure 4.



Gambar 1.9 Spin atau arah putar elektron

(a) (b)

Figure 4. (a) The Existence and Properties of Typological Caption (ii) in Book B, (b) The Existence and Properties of Typological Caption (i) in the Standard Book

Figure 4 (a) has a picture caption, namely "*Figure 1.9 Spin or direction of rotation of electrons*". In the description of the image is explained that the representation describes the spin or direction of rotation of electrons. In the image representation describes the direction of rotation of electrons are divided into two, namely clockwise (to the right) and counterclockwise (to the left) with a spin value that is also different. The value of the clockwise electron spin direction (to the right) is + ½ and the value of the counterclockwise electron spin direction (to the left) is -½. It can be seen that the description of the image does not explain as a whole or only explain part of the concept of the representation presented. Unlike the case with Figure 4 (b), it can be seen that the caption of the picture already explains the whole concept presented in the representation. Gkitzia et al., (2011) state that image captions are important, because image captions clarify the content and message of the representation and can show important parts of the image. Based on this, appropriate captions should be explicit, brief, comprehensive, providing autonomy to the representation. In addition, the right picture caption facilitates learning because students can understand the representation without seeing the related text.

Criteria (C5) Degree of Correlation Between Representations Comprising a Multiple One

This fifth criterion (C5) addresses the interrelationship between multiple representations that are clearly conveyed. This analysis focuses on the first criterion (C1) with multiple typologies. Chemistry textbook A shows the results that this textbook already contains two representations including ii) insufficiently linked, and iii) unlinked which is dominated by ii) insufficiently linked 67%. In chemistry textbook B, the Merdeka curriculum shows the results that this textbook already contains one representation and is dominant in C5, namely ii) insufficiently linked enough 100%. Representation example in figure 5.

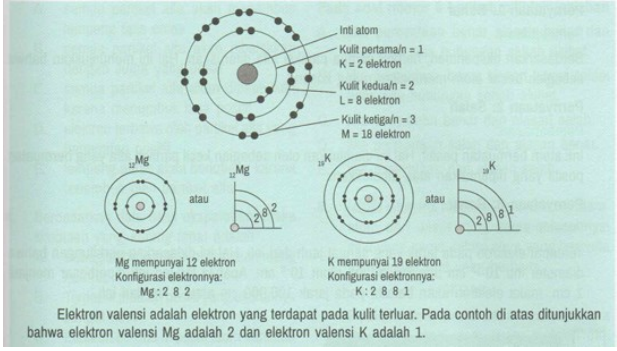


Figure 5. The Degree of Correlation Between Representations Comprising a Multiple One Unlinked Typological Representations in Book A

Figure 5 has been analyzed using the C1 criteria and is known to have a typology of multiple representations. Where multiple representations consist of sub-microscopic and symbolic representations. This representation includes two representations that represent the same phenomenon, namely the concept of electron configuration of the Bohr atomic model. This concept is represented in the form of sub-microscopic representations using black electrons contained in each atomic shell with different numbers and arrangements around the atomic nucleus (top), while symbolic representations use element symbols and also per-shell electron configurations that state the number of per-shell electrons in an atom (bottom). The level of connectedness between representations does not sufficiently describe and explain sub-microscopic representations and symbolic representations characterized by the absence of parallel positions and the absence of arrows connecting the two representations so that they are categorized as unlinked typologies. This is in accordance with the statement conveyed by Gkitzia et al., (2011) that representations with multiple typologies are said to be unlinked when the explanatory representations they include are only placed next to each other and there is no indication of equality of their surface features. Gkitzia et al., (2011) revealed that learners have difficulty in correlating the three levels of chemistry and connecting one level of representation to another. Therefore, learners should be taught the relationship between different types of representations in order to be able to connect one type of representation to another, and achieve a deep and conceptual understanding of chemical phenomena.

4. Conclusion

Analysis of multirepresentation in chemistry textbooks of the merdeka curriculum shows that in criterion C1 the types of representations in the chemistry textbooks of the Merdeka curriculum A and B are dominated by sub-microscopic and macroscopic aspects. Criterion C2 the interpretation of surface features are generally explicitly labeled in book A and book B. Criterion C3 the relatedness to text in book A and book B most of the representations show that they are completely related and linked to the representation text presented. Criterion C4

the existence and properties of a caption in book A is dominated by the no caption, while in book B there are existence of problematic caption. Criterion C5 the degree of correlation between representations comprising a multiple one in book A and book B is generally insufficiently linked.

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