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Description of Chemical Multirepresentation on Acid-Base Material in Merdeka Curriculum Chemistry Textbooks

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A B S T R A C T

The concept of acid-base is an essential and complex material because it is abstract. Textbooks play an important role in helping students' understanding through the use of representations to describe chemical phenomena that can make it easier for students to understand the material, especially on difficult material. However, the representations in the merdeka curriculum chemistry textbooks are generally sourced from websites or platforms that cannot be trusted. This study aims to analyze multirepresentation on acid-base material in the chemistry textbooks of the merdeka curriculum, using the method developed by Gkitzia. The data source in this study is the merdeka curriculum chemistry textbook which is generally used in SMA / MA Padang City. The results of this study show that textbook A and textbook B are dominant in the type of symbolic representation 64% and 50% (C1), book A and book B are generally explicit (C2), the relatedness to text, in book A is generally completely related and linked, book B is completely related and unlinked (C3), in book A and book B there is generally no caption (C4), the relationship between representations in book B is generally not quite related (C5).

1. Introduction

Acid-base is one of the materials studied by Phase F high school students. The concept of acid-base is one of the materials that is complex when viewed from the aspect of its characteristics has a subject matter that is classified as essential material and almost all of its concepts are abstract (Andriani & Ayu Dewi, 2019). Therefore, to understand the concept of acid-base, knowledge related to various fields of basic chemistry is needed, such as particles, molecular kinetic theory, properties and composition of solutions, atomic structure, ionization, covalent bonds, formulas, symbols, and equations, equilibrium and collision theory (Sheppard, 2007). According to research by Fajrin et al. (2020) on the overall subject matter of acid-base material showed that 47% of students experienced learning difficulties, and on the subject matter of calculating the pH of acidic and basic solutions showed the highest difficulty with a percentage of 88%. The same

is true of research conducted by Azizah et al. (2022) showed the occurrence of misconceptions in students with moderate categories in all acid-base concepts.

Regarding these problems through multirepresentation of chemistry, students can more easily understand, relate one theory to another and learn chemistry, especially on difficult material (Gilbert & Treagust, 2009) . The presentation of chemical multirepresentations in several forms, such as images, diagrams, text, tables, symbols and graphs can support students' ability to understand learning concepts (Gilbert & Treagust, 2009). The concept of acid-base is a concept that has chemical multirepresentation characteristics that include three levels of representation including macroscopic level, symbolic level, and sub-microscopic level. The macroscopic level represents real phenomena that can be found in the surrounding environment and can be seen with the naked eye. The sub-microscopic level is an aspect of representation with theoretical models in describing what happens at the molecular level (Gilbert & Treagust, 2009), while the symbolic level is a representation of reality that represents macroscopic phenomena in the form of images, symbols or formulas and uses chemical equations that can be described by a process (Andriani & Ayu Dewi, 2019; Gilbert & Treagust, 2009).

In the learning process, the use of chemical representations can support students' chemical literacy skills used to interpret and use chemical diagrams. Chemical literacy is a form of students' ability to connect macroscopic, sub-microscopic and symbolic level representations (Gilbert & Treagust, 2009). According to research conducted by (Nurisa & Arty, 2019), it was found that the chemical literacy of students regarding the concept of acid-base, in general, was still relatively low with a score of 48.62. The low level of chemical literacy indicates that students are still unable to connect the three levels of chemical representation. This is caused by the lack of application of learning to develop students' chemical literacy skills (Nurisa & Arty, 2019). Thus, textbooks are one of the important things to overcome this problem. Because textbooks are the main material in the learning process that must contain multirepresentation of chemistry to explain chemical phenomena in everyday life (Gilbert & Treagust, 2009). Textbooks based on chemical multirepresentations can help learners develop their own ideas and deepen knowledge of learning materials as well as develop thinking skills in higher categories (Gilbert & Treagust, 2009).

In addition, textbooks should be in accordance with existing curriculum requirements and meet applicable standards, and have conceptual validity, thus the textbook can be said to be a very effective teaching aid for teachers and students (Marpaung & Pongkendek, 2020). Along with the implementation of the merdeka curriculum through Permendikbud Number 56 of 2022, the textbooks used must be adapted to the characteristics and demands of this curriculum (Ginting et al., 2023). The learning process using the merdeka curriculum is designed to encourage “merdeka”, which provides flexibility to all students in learning activities (Rahayu et al., 2022). Therefore, teachers can choose and utilize the resources used in learning to facilitate learners' learning.

In supporting the achievement of an optimal learning process, the textbooks used by students need to receive great attention, because not all textbooks can be accepted by students. Based on the results of field observations of the merdeka curriculum chemistry textbooks in several schools in Padang City, it shows that the chemical representations provided in the merdeka curriculum chemistry textbooks are generally sourced from platforms or websites whose validity cannot be trusted or are not from standard books. Therefore, it is necessary to analyze multirepresentation in chemistry textbooks in order to analyze the extent to which textbooks are able to provide various forms of representation needed to understand learning materials. Previous research conducted by (Suryani & Latisma, 2019), regarding the analysis of chemical representations contained in 2013 curriculum chemistry textbooks, obtained results as the textbooks analyzed have met some of the criteria developed by Gkitzia et al. (2011). However, there is no similar study on the analysis of chemical multirepresentations in the merdeka curriculum chemistry textbook, especially on acid-base material. Based on this background, this analysis aims to analyze the extent to which the textbook meets the criteria for chemical representation by referring to standard books.

2. Methodology

This type of research is descriptive research. The data sources in this study are two chemistry textbooks of the merdeka curriculum of SMA/MA which are commonly used by schools in Padang City. The subjects in this study consisted of five coders including two chemistry lecturers at FMIPA, UNP, two other researchers, and the researcher himself. The research procedure involves several stages, namely: (1) Selection and sampling, the first step of the research was to make observations to the school, then take two high school chemistry textbooks/MA merdeka curriculum; (2) Coding and analysis, analysis was carried out on chemical representations in both textbooks using a rubric developed by Gkitzia et al. (2011); (3) Summarizing the results of the analysis, the results of the analysis of the two textbooks were compared with the standard book, namely Brady 7th edition with the title *Chemistry: The Molecular Nature of Matter and Change.* This comparison aims to assess the extent to which the representations in the merdeka curriculum chemistry textbooks meet the chemical representation standards. The research instrument used consists of a multirepresentation analysis sheet, and a reliability sheet. The data analysis technique in this study used the Krippendorff Alpha formula (Neuendorf, 2002).

$$\alpha = 1 - \frac{Do}{De}$$

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

This study aims to analyze multirepresentation in the merdeka curriculum chemistry textbook on acid-base material using the rubric of Gkitzia et al. (2011), each of which criteria is presented in table 1.

Table 1. Criteria and Typology of Chemical Multirepresentation

Criteria		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 representations comprising a multiple one	i. Sufficiently linked ii. Insufficiently linked iii. Unlinked

Source: (Gkitzia et al., 2011)

The criteria for chemical multirepresentation and each of its typologies can be explained as follows:

Criteria (C1): Types of representation. This criterion aims to analyze and identify what types of representations are presented and emphasized in the textbook. This criterion has six typologies including: (i) macro, (ii) submicro, (iii) symbolic, (iv) multiple, (v) hybrid, and (vi) mixed. A representation can be categorized as multiple when it describes a chemical phenomenon using two or three levels of representation, while hybrid when it combines two or three levels of representation to form a representation that complements each other and a representation can also be categorized as mixed when one of the three levels of representation and another type of representation are analogous simultaneously.

Criteria (C2): Interpretation of surface features. This criterion aims to analyze the extent to which the interpretation of surface features (elements that make up the representation) is clearly labeled or indicated. This criterion consists of three typologies including: (i) explicit, (ii) implicit and (iii) ambiguous. Explicit typology is when a surface feature of a representation is clearly labeled or indicated. If a surface feature or element of a representation is not clearly labeled or indicated then this representation is grouped with implicit codes, and for representations that do not indicate or label surface features at all then they are grouped with ambiguous codes.

Criteria (C3): Relatedness to text. This criterion aims to analyze the relationship of the representation to the text presented in the textbook and see if there is a

direct link from the text to the representation. This criterion consists of five typologies including: (i) completely related and linked, (ii) completely related and unlinked, (iii) partially related and linked, (iv) partially related and unlinked, (v) unrelated. A representation is categorized as completely related when it describes the exact content of the text. A representation is grouped under partially related when it depicts a subject similar to the text but not exactly the same or not completely. Conversely, a representation is coded as unrelated when it is not related to the text content. Then, a representation was coded as linked or unlinked, when the text referred to the representation using a direct link or not, i.e. with or phrases such as, "can be observed in the image".

Criteria (C4): Existence and properties of a caption. This criterion aims to analyze the captions of the representations presented in the textbook. The caption contained in the representation is very important, because it can clarify the content and message of the representation. This criterion consists of three typologies including: (i) Existence of appropriate caption (explicit, brief, comprehensive, providing autonomy), (ii) Existence of problematic caption, and (iii) no caption.

Criteria (C5): Degree of correlation between representations comprising a multiple one. This criterion can only be used to analyze C1 criteria with multiple typologies. This criterion aims to see the relationship between representations that are clearly shown. This criterion consists of three typologies including: (i) sufficiently linked, (ii) insufficiently linked, and (iii) unlinked. Representations are grouped in the sufficiently linked typology when the relationship between representations is clearly shown using symbols such as arrows. If the representations are only described as parallel or parallel without using symbols then the representations are grouped in the insufficiently linked, while if the representations are not clearly connected then the representations are grouped in the unlinked typology.

3. Results and Discussion

Chemical multirepresentation analysis on Acid-Base material was conducted on three chemistry textbooks including standard books, book A and book B. Multirepresentation analysis was carried out using criteria developed by (Gkitzia et al., 2011) which consisted of five criteria including criteria C1, C2, C3, C4 and for C5 criteria which were used to analyze multiple representation types only. The following are the results of the reliability test on the results of the multirepresentation analysis of standard textbooks, chemistry textbook A, and chemistry textbook B on Acid-Base material conducted by five coders, as follows:

a. Result reliability test

Reliability is the consistent series of measuring that gives the same results and is more subjective between coders in giving the same score (Sanaky et al., 2021). The reliability test aims to ensure that the results of the analysis carried out are

stable between coders and that the results of the study are acceptable (Creswell, 2014). This can allow researchers to be more confident in using the data from the analysis (Creswell, 2014). The following are the results of the reliability test obtained from the reliability test measurement, based on the chemical multirepresentation analysis carried out as follows:

Table 2. Inter-rater Reliability Measurement Results

Criteria		Value of α (reliability)	Description of reliability
C1	Type of representation	0,97	Strong
C2	Interpretation of surface features	0,94	Strong
C3	Relatedness to text	0,94	Strong
C4	Existence and properties of a caption	0,94	Strong
C5	Degree of correlation between representations comprising a multiple one	0,76	Moderate

The results of the reliability calculation showed that the analysis of chemical representations in standard textbooks, A, and B had $\alpha > 0.8$ (strong category) and $0.67 \leq \alpha < 0.8$ (medium category). The intra-rater reliability test conducted two weeks apart showed a reliability value of 1, with a strong category, with no change in the results of the analysis between the first and second weeks of the three books analyzed. This is in accordance with the statement of Sanaky et al. (2021), explaining that the results of the reliability test show consistent analysis without significant variation between coders, as well as consistent data even though measurements are taken repeatedly or in different time periods.

b. Results of chemical multirepresentation analysis

In the standard book there are 24 chemical representations, then in book A there are 11 chemical representations, and in book B there are 10 chemical representations. After that, chemical multirepresentation analysis was carried out using the criteria developed by Gkitzia et al. (2011) consisting of C1-C5 criteria. The following are the results of the representation analysis contained in the standard book, textbook A, and textbook B based on the agreement between coders shown in table 5 below:

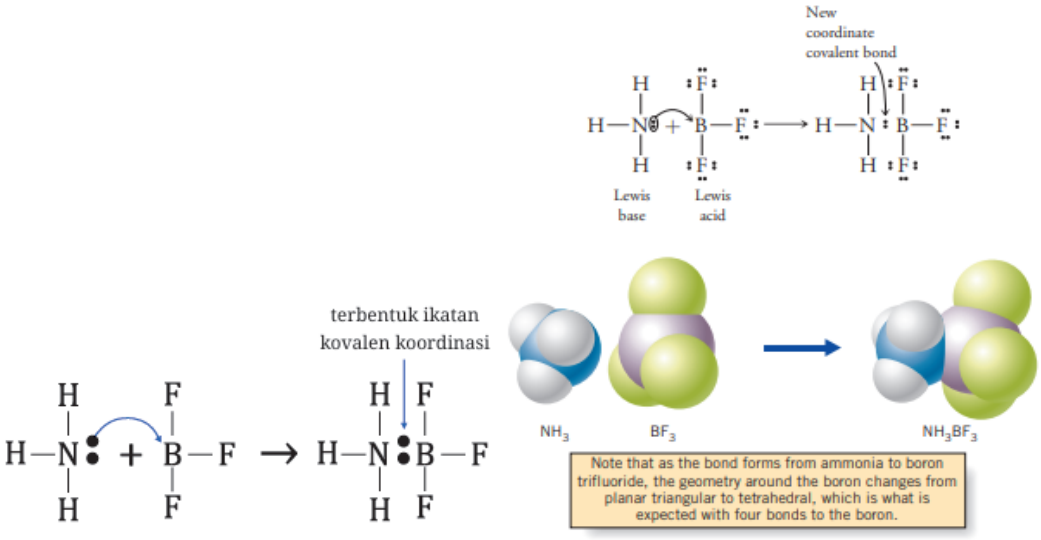
Table 3. Chemistry Multirepresentation Analysis Results

Criteria	Typology	Textbook Standard book	Percentage	Book A	Percentage	Book B	Percentage
C1	i	2	8%	3	27%	2	20%
	ii	4	17%	1	9%	0	0%
	iii	7	29%	7	64%	5	50%
	iv	7	29%	0	0%	2	20%
	v	4	17%	0	0%	1	10%
	iv	0	0%	0	0%	0	0%
C2	i	16	67%	5	45%	6	60%

Criteria	Typology	Textbook Standard book	Percentage	Book A	Percentage	Book B	Percentage
	ii	5	21%	1	9%	1	10%
	iii	3	13%	5	45%	3	30%
C3	i	17	71%	10	91%	0	0%
	ii	7	29%	1	9%	7	70%
	iii	0	0%	0	0%	0	0%
	iv	0	0%	0	0%	1	10%
	v	0	0%	0	0%	2	20%
C4	i	10	42%	3	27%	1	10%
	ii	0	0%	1	9%	3	30%
	iii	14	58%	7	64%	6	60%
C5	i	1	14%	0	0%	0	0%
	ii	5	71%	0	0%	2	100%
	iii	1	14%	0	0%	0	0%

Criteria (C1) Type of Representation

Textbook A and textbook B analyzed dominantly present symbolic representation types with a percentage of 64% and 50% respectively. Macroscopic representation types in textbook A and textbook B have almost the same percentage of 27% and 20% respectively. However, there are significant differences in the types of sub-microscopic, multiple and hybrid representations presented in book A and book B, where book A contains 9% types of sub-microscopic representations while book B does not contain any that are only presented at the sub-microscopic level, but this sub-microscopic level is integrated with the macroscopic level, known as multiple and hybrid, in accordance with what was stated by Gkitzia et al. (2011), the percentage of multiple and hybrid representation types in book B are 20% and 10% respectively, but book A does not contain these two types of representation. Figure 1 (a) is a representation contained in Book A with a symbolic representation type and Figure 1 (b) is a representation of the standard book used as a reference to see the representation in describing the same concept, namely the concept of Lewis Acid-Base theory.



(a) (b)

Figure 1. (a) Symbolic Representation Type Textbook A, (b) Multiple Representation Types (Symbolic and Sub-microscopic) in the Standard Book

The representation explains the concept of Lewis Acid-Base, G.N. Lewis proposed a theory of acid-base, in his theory, Lewis said that acids are species that accept free electron pairs to form coordination covalent bonds, while bases are species that provide free electron pairs so that coordination covalent bonds are formed (Chang, 2010). The chemical reaction equation depicted in the representation is between NH_3 and BF_3 molecules, this reaction forms the covalent bond compound NH_3BF_3. In book A, this concept is only presented with one type of representation, namely symbolic. However, when compared to the standard book this concept is described with multiple types of representation (symbolic and sub-microscopic).

In the sub-microscopic representation contained in the standard book described as colored balls to represent NH_3 and BF_3 molecules and NH_3BF_3 compounds, this can illustrate the concept of the molecular shape of the bond formed, where the geometric shape around boron changes from planar to tetrahedral segments (Jespersen et al., 2014). With this, learners get additional information and can clarify the meaning that can be conveyed with sub-microscopic representation types. Therefore, the representation in book A should be added to the representation at the sub-microscopic level so that it can provide an overview to learners about the concept of molecular shape. Thus, students can interpret other information or concepts besides the concept of lewis acid base that can be described through the sub-microscopic representation.

The use of symbolic representations in the form of chemical reaction equations alone, can make it difficult for students to visualize and understand the particulate nature of the material it represents and the chemical phenomena involved (Gkitzia et al., 2011). Therefore, the presentation of sub-microscopic representations is important in helping learners understand a concept or the phenomena involved (Gilbert & Treagust, 2009).

Criteria (C2) Interpretation of surface features

In C2 criteria contained in book A and book B in general are included in the explicit typology, with a percentage of 45% and 60% respectively. Representations with implicit typology found in book A and book B have almost the same percentage of 9% and 10% respectively. However, there is a significant difference in the ambiguous typology found in book A and book B at 45% and 60% respectively. Figure 2 is one example of representation with implicit surface feature interpretation.

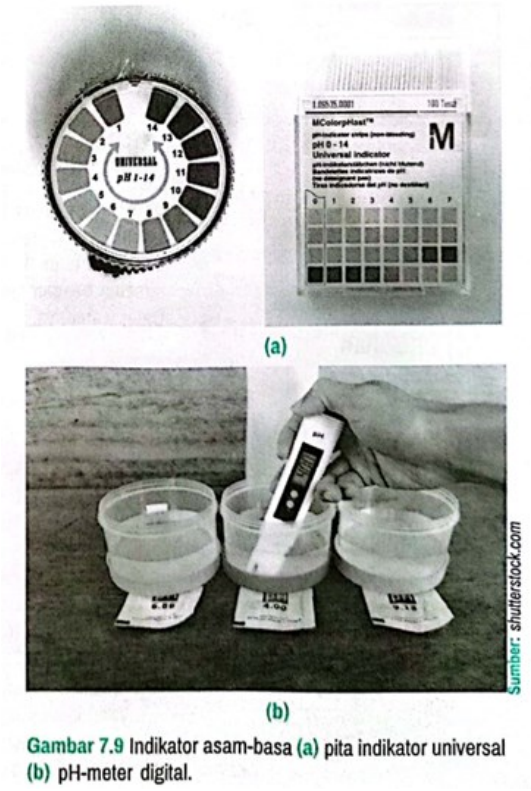
Figure 2. Interpretation of Implicit Surface Features in Book B

Figure 2, is an example of a representation found in book B with an implicit interpretation of surface features, because it only shows some of the surface features or elements that make up the representation clearly. The representation explains the properties of acidic and basic solutions. The acid-base solution test in the representation uses litmus paper. The representation only shows or labels the ions contained in the beaker containing the acid and base solution. However, it does not show or provide information about what solution is contained in each beaker, and what color changes occur on litmus paper. The litmus paper also does not show color changes that can be observed by students, which only provides black and white colors. Therefore, the representation can be explicit if the representation is added to the labeling of what solution is tested and shows the color of litmus paper after being tested in acidic and basic solutions, so that students can find out which solution is acidic or basic.

It's crucial to label or display every component in the depiction, thus it can aid pupils in comprehending an idea. However, this will only happen if students are able to interpret the representation well (Gkitzia et al., 2011). According to Gkitzia et al. (2011), simple chemical representations in textbooks do not guarantee to improve students' understanding in learning. Therefore, textbook writers should emphasize the elements contained in the representation.

Criteria (C3) relatedness to text

In the C3 criteria contained in book A and book B show a very significant difference, namely book A generally in typology i) completely related and linked with a percentage of 90%, while book B is dominant in typology ii) completely related and unlinked with a percentage of 70%, as seen in table 5, in book A there is not a single representation with typology ii), iii), iv), and v), while in book B there is not a single typology i), and iii) only. Figure 3 is an example of representation with unrelated typology in textbook B.



Gambar 7.9 Indikator asam-basa (a) pita indikator universal (b) pH-meter digital.

Figure 3. Type of Representation with Unrelated Typology in Textbook B

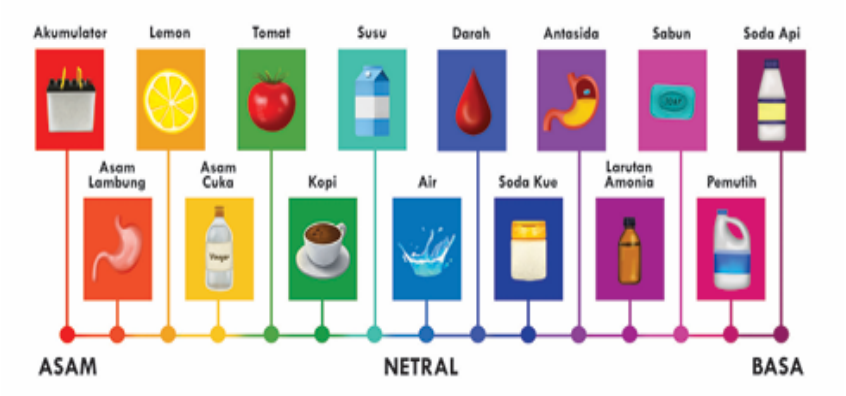
Figure 3 is an example of a representation that belongs to the typology (v) unrelated. It is said to be unrelated because the text content is not relevant to the picture given. The picture represents an acid-base indicator in the form of a universal indicator tape and a digital pH-meter, while the text content discusses a universal indicator solution and does not at all discuss the representation presented. Therefore, the representation should be depicted in accordance with the text content described, namely the universal indicator solution.

The representations presented in the textbook should be relevant and related to the concepts, principles, or phenomena described in the text, so that they can help learners in correlating the representations with the concepts described. Therefore, a textbook writer should pay attention to the relationship between images and text. If the image is related to the content of the text, then learners are able to understand the image and indirectly learners also easily understand the concepts discussed. According to the statement of (Wu & Shah, 2004), which states that in order for students to understand the relationship between chemical representations and supporting text, the two must be presented closely.

Criteria (C4) Existence and properties of a caption

The criterion aims to analyze the captions of the representations presented in the textbook. The data analyzed in Table 2 shows that the C4 criteria contained in Book A and Book B are generally classified as typology no captions, with a

percentage of 64% and 60% respectively. However, there is a significant difference in the typology of Existence of problematic caption, in book A as much as 9% while in book B as much as 30%. One example of the representation of a description accompanied by a problem contained in book A can be seen in Figure 4.



Gambar 1.4 Beberapa zat dan produk yang bersifat asam dan basa

Figure 4. Type of Representation with the Typology of Existence of Problematic Caption in Book A

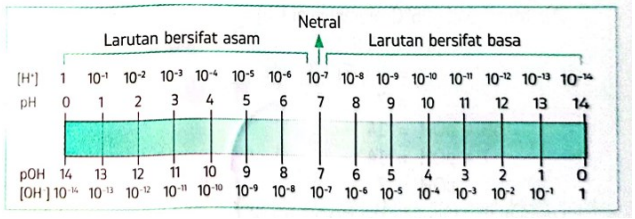
This representation represents examples of acidic, basic and neutral substances and products in everyday life. The description on the representation is "*Some substances and products that are acidic and basic*". This caption is said to be problematic because it is not comprehensive or thorough. When referring to the picture given, there is water shown with neutral properties, the caption should also include the word neutral, so that when students read the caption they can know that the representation shows several examples of substances or products that are acidic, basic, and neutral in everyday life.

One of the most crucial elements of a representation is its caption, which serves to elucidate its content and message. As a result, it is necessary to have appropriate, comprehensive, and clear captions with the representation in order to help learners comprehend its contents without having to view the related text (Gkitzia et al., 2011). The existence of problematic captions from representations contained in textbooks or without captions causes the content conveyed to be unclear, this can cause learners to have difficulty interpreting it (Gkitzia et al., 2011).

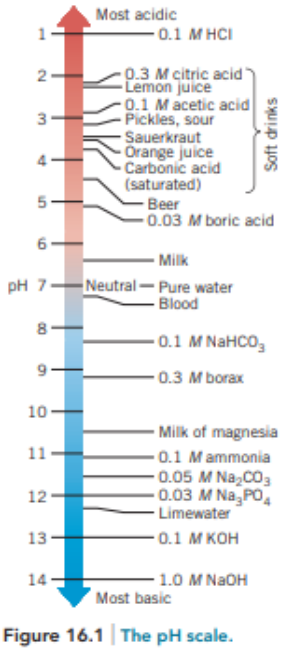
Criteria (C5) Degree of correlation between representations comprising a multiple one

This criterion aims to analyze how the relationship between chemical representations including macroscopic, sub-microscopic and symbolic are clearly connected. This criterion can only be used to analyze multiple representation types, thus only standard books and book B can be analyzed because book A does not contain multiple representation types. The data analyzed in Table 5 shows that

criteria C5 contained in book B 100% contains typology that is insufficiently linked. One example of a representation with insufficiently linked typology contained in book B can be seen in Figure 5.



(a)



(b)

Figure 5. (a) Types of Representation with Insufficiently linked Typology in Book B, (b) Types of Representation with sufficiently linked Typology in the Standard Book

Figure 5 (a), is a multiple representation that involves two levels of representation including macroscopic level and symbolic level. The macroscopic level is the acid-base and neutral pH scale with a range of 1 to 14. While the symbolic level is indicated by the concentration of H^+ and OH^-. This representation is grouped in the typology insufficiently linked because symbolic and sub-microscopic representations are placed in parallel or parallel, without being indicated by arrows or symbols between representations, so that learners can understand the equivalence of these representations. referring to standard books that describe the same concept, can be seen in Figure 5 (b) which is also a type of multiple representation (symbolic and macroscopic). This representation is said to be sufficiently linked because the representations are clearly connected using a dash. This shows that phenomena that occur at the macroscopic level are clarified by symbolic representations. This correlation or connection is very important in building relationships between the three levels of chemical representation (Gkitzia et al., 2011).

4. Conclusion

Analysis of multirepresentation in chemistry textbooks of the merdeka curriculum shows that in criteria C1 the type of representation contained in textbook A and textbook B is dominantly presented with the type of symbolic representation, then in criteria C2 the interpretation of surface features presented in textbook A and textbook B is generally explicit, while in criteria C3 the relatedness to text, in book A is generally completely related and linked, while in book B it is completely and unlinked, in criteria C4 the Existence and properties of a caption in book A and book B generally do no captions, and criteria C5 the Degree of correlation between representations comprising a multiple one in book B is generally insufficiently linked with a percentage of 100%, while in book A it is not possible to analyze criteria C5 because there is not a single type of multiple representation.

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