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An Analysis of Buffer Solution Topics in Chemistry Textbooks: Application of the 4 Step Teaching Material Development Criteria

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Abstract

Buffer solution content in Chemistry textbooks plays a significant role in achieving these educational objectives. This study aims to analyze buffer solution material in class XI Chemistry textbooks using the 4S TMD selection criteria, focusing on curriculum consistency, concept accuracy, and value education. A qualitative evaluative approach was employed, comparing the data collected from two textbooks (Book A and Book B) against established standards. The evaluation covered the scope and depth of the material, the accuracy of concepts, and the integration of values. The analysis found that both textbooks included six relevant concept labels, though Book B contained one overly general label. Regarding concept depth, Book A had two concepts with insufficient depth, while Book B had one overly shallow concept and one excessively detailed. Both books achieved the standard for concept accuracy. For value education, Book A integrated six core values, such as discipline and responsibility, while Book B incorporated eleven values, including creativity, democracy, and honesty. The findings suggest that Book A aligns more closely with the 4S TMD evaluation criteria than Book B. This highlights the importance of balancing curriculum alignment, conceptual depth, and value integration in educational materials.

Keywords: 4S TMD, buffer solution, chemistry textbooks

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1. Introduction

Education is a vital process that contributes to the development of a country by improving the quality of its human resources (UNESCO, 2020). Learning, as defined by Sanjaya (2011), is a process of behavior change driven by experience and practice, enabling individuals to enhance their quality of life. This perspective is further supported by Lachman (2010), who emphasizes that learning is a continuous process that evolves over time. The learning process involves three interrelated components: teachers, learners, and teaching materials. Teachers facilitate the acquisition of knowledge, while learners actively engage with the material to develop essential skills (Shulman, 2004). Teaching materials play a crucial role in bridging theory and practice, making complex concepts accessible to students (Anwar, 2015). The effective interaction of these components is critical for successful learning outcomes, as research indicates that well-designed teaching materials, alongside skilled teachers and motivated learners, are necessary for optimal educational results (Darling-Hammond et al., 2020).

Among the various fields of study that contribute to education, chemistry stands out as one that presents unique challenges due to its abstract nature. Chemistry is a branch of science that studies the nature, structure, and composition of matter, including its transformation into new substances and the accompanying energy changes (Djarwo, 2019). Many chemistry concepts are abstract, making them difficult for students to understand. In addition to the learning process itself, the role of textbooks also significantly impacts students' ability to comprehend chemistry (Rusianti & Fatah, 2019). A quality learning process requires appropriate learning resources, one of which is textbooks. In the 2013 curriculum, all student textbooks were replaced with books adapted to its guidelines.

To achieve an optimal teaching and learning process, quality teaching materials are essential. However, in reality, many teaching materials are not aligned with students' knowledge levels (Tekir & Akar, 2019). This misalignment can limit student engagement and comprehension, as highlighted in research. Sadler et al. (2013) found that teaching materials that fail to address students' prior misconceptions hinder their ability to grasp new concepts effectively. Similarly, Mouza and Lavigne (2013) emphasized that materials tailored to students' cognitive levels significantly improve learning outcomes by addressing their unique needs. Currently, textbooks used in schools are often criticized for their lack of alignment with curriculum guidelines and inaccuracies in their conceptual content. According to Muslich (in Anwar et al., 2017), teaching materials must meet several essential requirements, including conceptual accuracy. Another issue frequently encountered in the learning process is that the material presented by teachers is often either too broad, too narrow, too deep, or too shallow, failing to align with the skills expected by students (Mudlofir, 2011).

The alignment of textbooks with curriculum requirements has been extensively studied. Bajarias et al. (2024) highlighted teachers' experiences in effectively aligning curriculum content, while Johnson et al. (2020) reviewed curriculum reforms and their impact on teacher preparedness. Additionally, innovative approaches, such as using virtual reality in culturally relevant teaching, have been explored to enhance student engagement (Brown et al., 2021).

Building on this, research on teaching materials has highlighted their critical role in achieving desired learning outcomes. Anwar (2015) emphasized that even if techniques and strategies are well-executed, without quality teaching materials, learning outcomes will remain suboptimal. When assessing the quality of teaching materials, one key aspect is their alignment with the applicable curriculum. Low alignment between teaching materials and the curriculum makes it difficult to achieve the expected competencies (Lam & Tsui, 2013). This issue arises when educators rely on teaching materials without prior analysis to ensure their suitability.

To address the challenges of aligning textbooks with curriculum standards, effective analysis methods are required. One method to assess the quality of textbooks is by using the selection stage criteria outlined in the 4 Step Teaching Material Development (4S TMD) model, as proposed by Anwar (2015). This approach has been validated by multiple studies, emphasizing its reliability in evaluating content quality. Polikoff (2015) highlighted its effectiveness in aligning textbooks with curriculum standards, while Vaclavik et al. (2022) underscored its capacity to incorporate student perspectives, ensuring relevance and comprehensiveness in textbook evaluation.

The analysis incorporates three key criteria: conformity to curriculum demands, conceptual accuracy, and the values instilled in the textbook. The 4S TMD method is designed to produce ideal teaching materials and can also be used to analyze textbook content during the selection stage, ensuring alignment with curriculum guidelines, accuracy of concepts, and integration of values (Anwar & Noviyanti, 2017).

From the description above, several issues related to textbooks have been identified, including their alignment with curriculum guidance, the accuracy of concepts, and the integration of values. Research findings using the 4S TMD framework at the selection stage reveal these concerns. For example, Dewi (2016) concluded that buffer solution material in the analyzed textbook did not fully meet curriculum requirements. Buffer solutions, a challenging topic for students, require a strong understanding of equilibrium, acid-base concepts, and stoichiometry (Salame et al., 2022).

In terms of content breadth, Dewi's study found that the material was overly broad and failed to address the four concept labels required by learning indicators. Regarding depth, seven concepts lacked sufficient explanation, while one concept was explored in excessive detail. Similarly, Susila (2019) found that acid-base solution material in textbooks was not fully aligned with curriculum standards. The scope of content was deemed inadequate, as it did not cover the required four standard concept labels. These findings indicate that chemistry textbooks for high school/Islamic high school students often display discrepancies with curriculum demands, contain incorrect concepts, and lack integrated values. This highlights the importance of analyzing textbooks based on the 4S TMD selection criteria.

Stephanie et al. (2019) emphasized that buffer solution material requires students to have a strong grasp of mathematical reasoning and skills. Furthermore, understanding buffer solutions necessitates foundational knowledge of equilibrium, acid-base concepts, and stoichiometry to ensure comprehensive comprehension of the material.

This study aims to differentiate itself by providing an in-depth analysis of buffer solution topics through the lens of the 4S TMD framework. Unlike previous research, which primarily addressed general chemistry topics or broad curriculum alignment, this study delves into the specific content quality, conceptual depth, and pedagogical coherence of buffer solutions. By addressing gaps in previous studies, it offers a unique perspective on how these materials can be refined to better support student understanding and align with curriculum standards.

2. Research Method

This study uses a qualitative approach where the data collected from the object of this research is more in the form of words than numbers. The research method itself is the evaluative research method, which is a type of research that uses criteria or standards as a comparison of the data obtained. That way, it can be known the gap in the condition of the research object with the criteria or standards that have been set. Based on these results, an overview of whether the research object is suitable, less appropriate, or not in accordance with the standards that have been set (Arikunto, 2013).

In this study, the focus of the research is the buffer solution material in Senior High School/Islamic Senior High School class XI chemistry textbooks which is analyzed based on the criteria for the selection stage of the 4S TMD method, including the suitability of the material with curriculum guidance, the truth of the concept, and the cultivation of values.

2.1. Data Collection Technique

The data collection techniques in this study were conducted through three stages: the planning stage, the implementation stage, and the final stage. In the planning stage, the activities included selecting two high school chemistry textbooks to be analyzed. The textbooks chosen met the requirements based on the Ministry of Education and Culture Decree Number 148/P/2016 regarding the designation of textbook titles for specialized high school programs. The textbooks used were Textbook A, "Chemistry for High School/Islamic Senior High School Grade XI for Mathematics and Natural Sciences Program," and Textbook B, "Student Book: Active and Creative Learning Chemistry for High School/Islamic Senior High School Grade XI for Mathematics and Natural Sciences Program." The researcher also determined the material to be analyzed, which was the buffer solution topic in both textbooks.

In the implementation stage, three main steps were carried out. First, textbook compliance with curriculum standards was analyzed by identifying relevant basic competencies (BC), developing learning indicators (LIs), and validating them with two chemistry education experts. Revisions were made until the indicators were deemed valid. The analysis compared concept labels in the research objects with standard concepts to assess the material's breadth and depth. Second, conceptual accuracy was evaluated by comparing textbook concepts with standard concepts, omitting overly in-depth concepts to meet standards. Third, value integration was analyzed by identifying text sections aligned with the 18 values described in Balitbang (2010) guidelines.

In the final stage, the results were analyzed descriptively and objectively to provide comprehensive discussions. The researcher then drew conclusions based on the validated findings. Validation at each stage was emphasized to ensure the accuracy and reliability of the data and research results.

2.2. Analysis of Material Suitability with Curriculum Guidance

The analysis of conformity with the demands of the curriculum required data are basic competencies in the cognitive aspect (Buffer Concept) of Curriculum 2013 according to the material under study, standard concept labels of valid learning indicators, explanations of standard concepts in international general chemistry textbooks (textbooks), explanations of concepts in the object of research, and concept labels on the object of research. The data is used to analyze the breadth and depth of concepts on the object under study by comparing the object of research with standard concepts. In the material breadth analysis, the data used are standard concept labels and research object concept labels. Then, explanations of standard concepts and research object concepts are used in the concept depth analysis.

2.3. Concept Correctness Analysis

In the truth of the concept, the data needed to analyze the truth of the concepts in the research object are standard concept labels, standard concept explanations, and concept explanations on the research object. The truth of the concept on the object of research is done by comparing the explanation of the standard concept with the explanation of the concept on the object of research.

2.4. Value Planting Analysis

The data analysis technique used to examine value instillation in the research object is the content analysis method, involving systematic and objective document analysis. Text sections containing explicit or implicit value instillation are carefully analyzed for their relevance to the value descriptions and indicators of value integration, as outlined in the Balitbang (2010) guidelines, to ensure a comprehensive understanding of the underlying value transmission. This method helps identify patterns, themes, and relationships in the text, providing insights into how values are communicated, reinforced, and embedded.

3. Result and Discussion

3.1. Planning Stage

In the planning stage, the textbook used is a class XI chemistry textbook on buffer solution material which has been declared feasible by the Minister of Education and Culture of the Republic of Indonesia No. 148/p/2016. The books used are textbook A published by Erlangga and textbook B published by Grafindo.

3.2. Implementation Stage

The suitability of the material with curriculum guidance is measured by analyzing the breadth of material and the depth of concepts. In analyzing the suitability of the material, basic competencies, GPA, and standard concept labels are needed in accordance with curriculum guidance.

The material breadth analysis of buffer solution content in textbook A reveals six concept labels that align with the curriculum guidance. These results are summarized in Table 1, which presents the analysis of the breadth of buffer solution material in the textbook.

Table 1. Analysis of the Breadth of Buffer Solution Material in Textbook A

Standard Concept Labels From the Standard Book	Concept Labels on Research Objects Book A	Extent			Description
		LE	S	TW	
Definition of buffer solution	Definition of buffer solution	-	√	-	The research object contains all standard concept labels
Components of Buffer Solution	Composition of buffer solution	-	√	-	Research object contains all standard concept labels
Buffer Solution Capacity	Effectiveness of buffer solution	-	√	-	The research object contains all standard concept labels
How buffer solution works	Working principle of buffer solution	-	√	-	The research object contains all standard concept labels
Calculation of pH of buffer solution	pH value of buffer solution	-	√	-	Research objects load all standard concept labels
The role of buffer solution	Buffer solution in daily life	-	√	-	The research object contains all standard concept labels

Description: LE: Less Extensive, S : Suitable , TW : Too Wide

Sourced on the proceeds of the analysis in Table 1 regarding the breadth of buffer solution material on the object of research book A obtained zero (0) concept labels that are less extensive, six (6) concept labels included in the appropriate criteria and zero (0) concept labels that are too broad.

Table 2. Analysis of the Breadth of Buffer Solution Material in Textbook B

Standard Concept Labels from the Standard Book	Concept Labels on Research Object Book B	Extent			Description
		LE	S	TW	
Definition of buffer solution	Definition of Buffer Solution	-	√	-	The research object contains all standard concept labels
Components of Buffer Solution	Properties of buffer solution	-	√	-	The object of study contains all standard concept labels
-	Making buffer solution with specific pH	-	-	√	The research object contains concept labels that are not contained in the standard concept labels
Buffer Solution Capacity	Buffer Solution Capacity	-	√	-	The research object contains all standard concept labels
How buffer solution works	Working Principle of buffer system	-	√	-	The research object contains all standard concept labels
Calculation of pH of buffer solution	Calculation of pH of buffer solution	-	√	-	The research object contains all standard concept labels
The role of buffer solution	Buffer solution in the body of living things	-	√	-	The research object contains all standard concept labels

Description: LE: Less Extensive, S : Suitable , TW : Too wide

Sourced from Table 2, the analysis of the breadth of buffer solution material in research object B indicates that there are zero (0) concept labels categorized as less broad, six (6) concept labels meeting the appropriate criteria, and one (1) concept label identified as too broad. The concept identified as too broad pertains to "making a buffer solution with a specific pH," which includes material not covered in the standard concept labels outlined in the curriculum. This inconsistency highlights the need for strict alignment with curriculum standards to ensure that students focus on relevant and essential concepts (Lam & Tsui, 2013).

A comparison with research object A reveals that the breadth of material in book A meets the appropriate criteria, whereas book B includes content beyond the curriculum's scope. This observation aligns with findings by Muslich (in Anwar et al., 2017), who emphasized that teaching materials must adhere to curriculum guidelines to ensure effective learning outcomes.

The concept depth analysis further highlights the importance of balancing conceptual coverage. Insufficient depth can lead to misconceptions, as students may struggle to grasp the foundational principles, while excessive depth can overburden learners and reduce engagement (Sadler et al., 2013). Concepts were categorized into three levels: Less Deep, Suitable, and Too Deep. Based on the analysis of object A regarding buffer solution material, two concepts were classified as Less Deep, four as Suitable, and none as Too Deep. These results, as shown in Table 3, emphasize the need for an optimal depth that facilitates understanding while avoiding unnecessary complexity (Polikoff, 2015).

The findings suggest that object A provides a more balanced depth and breadth compared to object B, ensuring alignment with both curriculum demands and pedagogical goals. As previous studies have shown, teaching materials that align well with curriculum standards enhance student comprehension and minimize cognitive overload (Dewi, 2016; Susila, 2019). Therefore, addressing the issues identified in object B is crucial to improving its effectiveness as a teaching resource.

Table 3. Concept Depth Analysis of Buffer Solution Material in Book A

Concept Label in Book A	Depth		
	LD	S	TD
Definition of buffer solution	✓	-	-
Composition of buffer solution	-	✓	-
Effectiveness of buffer solution	✓	-	
Working principle of buffer solution	-	✓	-
pH value of buffer solution	-	✓	-
Buffer solution in daily life	-	✓	-

Description: LD; Less Deep, S; Suitable, TD; Too Deep

On the object of book B of buffer solution material, one (6) concept is obtained which includes deep criteria, one (1) concept that is too deep, and one (1) concept that is less deep. The proceeds of the analysis can be seen in Table 4.

Table 4. Concept Depth Analysis of Buffer Solution Material in Book B

Concept Label in Book B	Depth		
	LD	S	TD
Definition of Buffer Solution	-	✓	-
Properties of buffer solutions	-	✓	-
Making buffer solution with specific pH	-	-	✓
Buffer Solution Capacity	✓	-	-
Working Principle of buffer system	-	✓	-
Calculation of pH of buffer solution	-	✓	-
Buffer solution in the body of living things	-	✓	-

Description: LD; Less Deep, S; Suitable, TD; Too Deep

Sourced on the analysis of concept depth for both research objects, it was found that Book A falls into the insufficient depth category, while Book B falls into the depth not yet appropriate category.

3.3. Analysis of Conceptual Correctness in Textbooks

The following are the results of the conceptual correctness analysis which can be seen in Table 5 and Table 6.

Table 5. Analysis of the Correctness of the Concept of Buffer Solution in Textbook A

Concept Label in Book A	S	NyA
Definition of buffer solution	✓	-
Composition of buffer solution	✓	-
Effectiveness of buffer solution	✓	-
Working principle of buffer solution	✓	-
pH value of buffer solution	✓	-
Buffer solution in daily life	✓	-

Table 6. Analysis of the Correctness of the Concept of Buffer Solution Material in Book B

Concept Label in Book B	S	NyA
Definition of Buffer Solution	✓	-
Properties of buffer solution	✓	-
Making buffer solution with specific pH	✓	-
Buffer Solution Capacity	✓	-
Working Principle of buffer system	✓	-
Calculation of pH of buffer solution	✓	-
Buffer solution in the body of living things	✓	-

Description: S: Suitable, NyA: Not yet Appropriate

In the identification of concept accuracy analysis for research object A, as shown in Table 5, there are six (6) concepts with appropriate characteristics and zero (0) concepts with inappropriate characteristics. For Book B, as shown in Table 6, there are seven (7) concepts with appropriate characteristics and zero (0) concepts with inappropriate characteristics. Therefore, it can be concluded that both books have accurate concepts.

3.4. Analysis of Value Planting of Buffer Solution Material in Textbooks

In the analysis of value planting in research object A and research object B is done by analyzing the buffer solution material in each part of the book. After the material is analyzed, the values embedded in the material are identified by referring to the standards in the form of descriptions and indicators of value planting from the Ministry of National Education and Balitbang (2010). Sourced on the proceeds of the analysis of the buffer solution material and sourced on the reference of the value planting of the Ministry of National Education and Research and Development, research object A and research object B found different value planting.

The following Table 7 shows some of the proceeds of the identification of values embedded in the research objects.

Table 7. Table of Relationship between Solution Concentration and Acidity Level

No	Textbook A	No	Textbook B
1	Discipline	1	Hard work
2	Hard work	2	Independent
3	Responsibility	3	Responsibility
4	Friendly / communicative	4	Discipline
5	Love to read	5	Creative
6	Curiosity	6	Democratic
		7	Friendly / communicative
		8	Love to read
		9	Respect for achievement
		10	Curiosity
		11	Honest

Sourced on the proceeds from the tables above, it can be observed that both Book A and Book B contain varying values. Book A includes 6 values: discipline, hard work, responsibility, friendliness/communication, love for reading, and curiosity. Meanwhile, Book B includes 11 values: hard work, independence, responsibility, discipline, creativity, democracy, friendliness/ communication, love for reading, appreciation for achievement, curiosity, and honesty.

4. Conclusion

Analysis of the buffer solution material in textbooks A and B for Senior High School/Islamic Senior High School Class XI based on the 4S TMD criteria shows that textbook A is better aligned with the curriculum in terms of breadth, with all six concept labels meeting the standards, although two lack sufficient depth. Textbook B also aligns with six labels, but includes one irrelevant and overly broad concept, and its depth varies, with one label insufficient and another overly detailed. Overall, textbook A is recommended for its better alignment in breadth, although both books need improvement in depth. Both textbooks include scientifically accurate concepts. Textbook A integrates six character values, including discipline and responsibility, while textbook B integrates eleven, adding values such as creativity and honesty.

To improve chemistry textbooks, future efforts should focus on increasing the depth of content, integrating contextual and problem-based learning, and using digital tools to foster critical thinking and problem-solving skills. In addition, emphasising 21st century skills such as creativity and collaboration will better equip students to face global challenges.

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