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Didactic Reduction of Scientific Concepts Using Cirebon Batik as a Context-Based Learning Approach

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ABSTRAK

Pendidikan kimia seringkali menghadapi tantangan dalam menarik minat siswa SMA karena kompleksitas materi pelajaran. Penelitian ini mengusulkan pendekatan berbasis konteks, memanfaatkan kekayaan warisan budaya Batik Cirebon, untuk meningkatkan pemahaman siswa tentang konsep-konsep kimia. Dengan mengintegrasikan kearifan lokal ke dalam kurikulum, penelitian ini bertujuan untuk menjembatani kesenjangan antara pengetahuan ilmiah abstrak dan aplikasi dunia nyata. Penelitian ini menggunakan Model Rekonstruksi Pendidikan (MER) untuk menganalisis konten ilmiah dalam pembuatan batik dan menerapkan strategi reduksi didaktik untuk menyederhanakan konsep-konsep kompleks. Penelitian ini menemukan bahwa dengan menghilangkan elemen kompleks, menggunakan visualisasi, dan menggunakan analogi, konten ilmiah dapat dibuat lebih mudah diakses oleh siswa SMA. Hasil penelitian ini menunjukkan bahwa pendekatan berbasis konteks, dikombinasikan dengan reduksi didaktik, dapat secara signifikan meningkatkan pemahaman dan apresiasi siswa terhadap kimia.

ABSTRACT

Chemistry education often faces challenges in engaging high school students due to the complexity of the subject matter. This study proposes a context-based approach, utilizing the rich cultural heritage of Cirebon Batik, to enhance students' understanding of chemistry concepts. By integrating local wisdom into the curriculum, the study aims to bridge the gap between abstract scientific knowledge and real-world applications. The research employs the Model of Educational Reconstruction (MER) to analyze the scientific content within batik-making and implement didactic reduction strategies to simplify complex concepts. The study found that by removing complex elements, utilizing visualizations, and employing analogies, the scientific content could be made more accessible to high school students. The results of this study suggest that a context-based approach, combined with didactic reduction, can significantly improve students' understanding and appreciation of chemistry.

1. INTRODUCTION

Chemistry education at the high school level often encounters challenges, primarily due to the complexity of the content, which is difficult for students to grasp. This issue is exacerbated by instructional approaches that tend to be abstract and lack relevance to students' daily lives. Consequently, students frequently lose interest in developing a deeper understanding of chemistry (Pilot & Bulte, 2021). One viable solution is a context-based approach that integrates local wisdom into learning. This approach establishes relevance by connecting science to students' real-world experiences, thereby enhancing their interest and understanding of chemistry concepts (Holbrook & Rannikmae, 2018).

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Cirebon Batik serves as an excellent example of local wisdom that holds significant potential for utilization as a context in chemistry education. The batik-making process encompasses several chemistry concepts, including fabric polymerization, redox reactions in dyeing, and molecular interactions during color fixation (Anugrah, 2021). Polymerization in fabrics involves the chemical structure of natural or synthetic fibers, comprising monomers with specific functional groups such as hydroxyl, carbonyl, and carboxyl. Dyes like naphthol and indigosol employ redox reactions to produce permanent colors on fabrics. Furthermore, molecular interactions between dyes and fabric fibers are governed by chemical functional groups that determine solubility and dye affinity (Anugrah, 2021). However, this scientific content is inherently complex and often unsuitable for the cognitive level of high school students (Niebert & Gropengiesser, 2015).

To bridge this gap, an approach is needed to simplify the content without losing its scientific integrity. Didactic reduction is a key step in adapting scientific content to align with the cognitive levels of high school students. According to Anwar (2010), didactic reduction involves a series of measures to make scientific material more accessible to students by removing complex elements, altering the format of presentation, employing visualizations, and particularizing the content. In the context of chemistry learning based on Cirebon Batik, didactic reduction not only simplifies the content but also preserves the connection between chemistry concepts and their real-life applications. This approach enables students to understand chemistry within a culturally relevant context while simultaneously enhancing their scientific literacy (Duit et al., 2012).

This study adopts the Model of Educational Reconstruction (MER) as the primary framework for integrating the context of Cirebon Batik into chemistry learning. MER is frequently used to adapt complex scientific content into relevant and cognitively appropriate learning materials (Przybylla & Romeike, 2016). This model comprises three key stages: content structure analysis, investigation of students' perspectives, and evaluation of instructional design. The focus of this research is on the didactic reduction stage to produce chemistry learning materials based on Cirebon Batik that are both effective and comprehensible. This study not only contributes to the development of chemistry learning materials based on local wisdom but also provides a model of didactic reduction implementation applicable to other learning contexts. This approach holds broad implications for enhancing the quality of STEM-based chemistry education in Indonesia, particularly through leveraging cultural heritage such as Cirebon Batik.

2. METHOD

This research employs a descriptive-qualitative approach using the Model of Educational Reconstruction (MER) as the primary framework. The main focus is on analyzing content structure and implementing didactic reduction processes to simplify scientific materials based on Cirebon Batik to suit high school chemistry learning. The study consists of the following stages:

Scientific Content Analysis of the Batik Context

This stage identifies the scientific elements inherent in the Cirebon Batik-making process, such as fabric polymerization, redox reactions in dyes, and molecular interactions. Each element is analyzed to determine its complexity level and relevance to the high school chemistry curriculum. The scientific content structure analysis is based on references from four articles and books covering three primary batik components: fabric, dyes, and wax.

Comprehensibility Testing

This test assesses how well students understand the didactically reduced text. Each paragraph is evaluated through a format for identifying the main ideas. Respondents include 30 high school seniors who independently read the paragraphs and summarize the main ideas in concise sentences. Their responses are scored as follows:
0 = incorrect
1 = partially correct
2 = completely correct
Reader comprehensibility levels are calculated using the formula:

$$K = \frac{Jb}{S \times score\ max} \times 100\% \quad (1)$$

where
K = comprehensibility level
Jb = number of correct answers
S = number of respondents
According to Arifin (2015), if the result is below 67%, further didactic reduction is required

The didactic reduction process

The didactic reduction process follows the eight methods outlined by Anwar (2010), such as removing complex elements, converting narratives to qualitative descriptions, utilizing visualizations, and particularizing content. The instruments used include a didactic reduction format based on the scientific content structure of batik. This process is validated by three chemistry experts to ensure that the didactic reductions align with students' perceptions. The resulting reduced texts are used as teaching materials composed of thematic paragraphs tailored to literacy-based learning stages.

3. RESULT AND DISCUSSION

Result

In this section, the results of the three stages of research that have been conducted will be discussed, namely: 1) the results of the analysis of the scientific structure of the context, 2) the comprehension test of the basic text (which parts need to be reduced-didactically), and 3) the process of didactic reduction (the context and the chosen didactic reduction methods).

Scientific Content Structure Analysis Results

Batik involves identifying chemistry topics present in the batik-making process, such as fabric polymers, redox reactions in dyeing, and molecular interactions between chemical compounds and fabric fibers. The analysis reveals that the batik-making process scientifically involves several complex chemistry concepts, such as polymerization in fabrics (including natural and synthetic fibers), redox reactions in the dyeing process using naphthol and indigosol, as well as molecular interactions between chemical compounds that influence the final color on the fabric. The following are the primary references relevant to the content structure analysis in developing chemistry teaching materials based on Cirebon Batik:

Tabel 1. Main References for the Scientific Structure Analysis in the Context of Cirebon Batik

No	Author	Title	Contribution
1	Anugrah (2021)	Scientific content analysis of batik Cirebon and its potential for high school STEM-approached project-based instruction	The scientific components of the batik-making process include the chemical composition of fabric, wax, and dyes. Relevant high school chemistry concepts such as polymers, redox reactions, and the functional group structures of organic compounds are analyzed and mapped into the curriculum framework.
2	Tímár-Balázsy & Eastop (2021)	Chemical Principles in Textile Conservation	The chemical composition of fabric, wax, and dyes used in the textile process. In the context of Cirebon Batik, the concepts of fabric polymerization, the role of functional groups in dyeing, and molecular interactions are explained in detail. This knowledge aids in developing scientific content related to the molecular structure of polymers (fabric) and dyeing reactions.
3	Malik et al. (2016)	The Effect of Tawon Wax Composition on the Production of Klowong Batik on the Quality of Batik Results	The characteristics of wax, including its chemical structure composed of fatty acid esters and long-chain alcohol compounds. This knowledge is relevant in explaining the role of wax in the batik process, such as its hydrophobic properties that prevent dye from contacting the fabric during selective dyeing stages.
4	Chakraborty (2015)	Dyeing with solubilised vat dye in Fundamentals and Practices in Colouration of Textiles	The chemical reactions occurring in the fabric dyeing process, such as the use of naphthol and indigosol. Redox reactions, molecular interactions, and the role of dye functional groups in determining affinity to the fabric serve as the foundation for developing scientific content elements of Cirebon Batik.

From a pedagogical perspective, an analysis was conducted on the alignment between the Core Competencies (KI) and Basic Competencies (KD) of high school chemistry according to the 2013 Curriculum, focusing on chemistry concepts related to the context of Cirebon Batik. This analysis also considered cognitive and attitudinal learning objectives referring to PISA competencies. The relationship between context, content, curriculum structure, and learning objectives based on PISA competencies is presented in Table 2 below.

Table 2. The Relationship Between the Basic Competencies of the 2013 Curriculum and the Cognitive Learning Objectives of PISA Competencies

Sub-context	Content	Basic Competency	Indicator	Cognitive Learning Objective
Fabric	Polymers (Grade XII)	3.11 Analyzing the structure, nomenclature, properties, and classification of macromolecules.	1. Explain types of monomers, types of polymerization reactions, polymers in daily life, etc. 2. Explain the formation of addition and condensation polymerization.	1. Students can attribute the concept of monomers and polymers to the types of basic batik fabrics. 2. Students can distinguish between addition and condensation polymerization processes for each type of basic batik fabric.
Wax	Macromolecules (Grade XII)	3.11 Analyzing the structure, nomenclature, properties, and classification of macromolecules.	1. Explain the structure of fats. 2. Explain the properties of fats and oils.	1. Students can attribute the chemical structure of fats and their influenced properties. 2. Students can differentiate between the structure of fats and oils, as well as their physical and chemical properties.
Batik dyes	Organic Compounds (Grade XII)	3.9. Analyzing the structure, nomenclature, properties, synthesis, and uses of carbon compounds.	1. Explain the structure, nomenclature, properties, and uses of benzene and its derivatives. 2. Relate the structural formulas of compounds to their chemical properties.	1. Students can attribute the unique structures found in batik dyes. 2. Students can attribute the chemical properties related to the chemical structure of batik dye components.
Interaction of batik dyes with fabric	Chemical Bonds (Grade X)	3.5. Comparing ionic bonds, covalent bonds, coordinate covalent bonds, and metallic bonds, and their relation to substance properties.	1. Describe the formation of ionic, covalent, and metallic bonds.	1. Students can attribute the principles of chemical bond formation between dyes and fabrics.
Batik dyeing mechanism using naphthol	Acid-Base Reactions (Grade X)	3.10. Explaining the concept of acids and bases, their strengths, and ionization equilibrium in solutions.	1. Predict the results of acid-base reactions.	1. Students can attribute the results of acid-base reactions in the batik dyeing process.
Batik dyeing mechanism using indigosol	Oxidation-Reduction Reactions (Grade X)	3.9 Identifying oxidation and reduction reactions using the concept of oxidation numbers of elements.	1. Explain the concept of oxidation-reduction.	1. Students can attribute the concepts of oxidation and reduction in batik dyeing.

The comprehensibility test

The comprehensibility test of the basic text was conducted to identify sections within the explanation of the scientific structure that require simplification or reduction to make them more accessible to students. In this test, students were asked to read the text explaining the batik-making process and identify the main ideas of each paragraph. Based on the results of the test, it was found that several sections of the text containing scientific explanations of chemical reactions (such as redox mechanisms and polymer structures in fabrics) were difficult for students to understand. Specifically, three key sections were identified as requiring didactic reduction, as shown in Table 3 below.

Table 3. Comprehensibility Test Results

No	Context	Description
1	Polymerization of Fabric	The batik-making process begins with the selection of fabric, mostly consisting of natural fibers like cotton and silk, which have a polymer structure. Polymers are large molecules composed of repeating monomer units. The polymer structure in fabric fibers influences their ability to absorb dyes, which in turn affects the quality and durability of the color on the fabric.
2	Chromophore Groups in Dyes	Chromophore groups are parts of dye molecules responsible for absorbing light and giving the substance its color. These groups consist of a series of carbon double bonds that enable the molecule to absorb specific wavelengths of light in the electromagnetic spectrum. In the context of Cirebon Batik, chromophore groups in dyes, such as naphthol or indigosol, absorb light at specific wavelengths, producing colors visible to the human eye.
3	Principle of Electromagnetic Radiation in Batik Dyeing Process	Electromagnetic radiation plays a crucial role in the batik dyeing process. The dyes on the fabric absorb light in the form of electromagnetic radiation, covering a range of wavelengths from ultraviolet rays to visible light. This process occurs when chromophore groups in dye molecules absorb energy from electromagnetic radiation, causing electrons within the molecules to move to higher energy levels. This energy transfer results in color changes on the fabric, which are visible to the human eye.
4	Redox Reactions in Dyeing	In batik dyeing, dyes such as naphthol and indigosol are used to impart color to the fabric through redox reactions. These reactions involve changes in the oxidation state of dye molecules, transforming them from a colorless form to a colored one after electron transfer between the dye and other chemicals. This process is essential for achieving strong and permanent colors on batik fabric.

The four topics mentioned above require a didactic reduction process to ensure that the material delivery aligns with students' cognitive development and the scope of the curriculum. The concept of polymers and the polymerization process is quite technical and requires a deeper understanding of chemical bonding between monomers. An overly detailed explanation of the types of polymers or covalent bonds within fabric fibers could hinder students' comprehension. Similarly, understanding how chromophore groups absorb light and influence color often requires knowledge of electromagnetic radiation and the interaction between light and matter. The absorption process at the molecular level can be challenging to grasp without appropriate visualizations. Concepts such as electromagnetic radiation, wavelengths, and the interaction between light and molecules are often difficult for students to understand without a foundational knowledge of physics and chemistry. Therefore, explanations of these principles need to be simplified and supported with analogies that are easier for students to comprehend. In the dyeing process, redox reactions are often confusing for students because they involve changes in electrons and atoms at the molecular level. Explanations of redox mechanisms, including free electrons in dyes and their interactions with fabric fibers, need to be simplified to make them more accessible to students.

Didactic Reduction Process

Based on the comprehensibility test results, it was found that the four sections above contained highly technical chemistry concepts and required simplification to be easily understood by students. Explanations about fabric polymer structures, chromophore groups, electromagnetic radiation, and redox reactions were often considered too abstract and complex for high school students, necessitating adjustments to their cognitive level.

1. Fabric Polymerization This section explains the structure of fabric polymers composed of repeating monomers and how the polymer structure affects the fabric's ability to absorb dyes. It is overly technical and challenging for students without an adequate background in chemistry. Concepts like chemical bonding between monomers and their effects on the quality of batik dyeing are too complicated for students at this level. Thus, the explanation needs to be simplified, using more accessible language and avoiding technical terms like "monomer" and "covalent bonds."
2. Chromophore Groups in Dyes Chromophore groups are components of dye molecules that influence their ability to absorb light and impart color to substances. This explanation uses abstract concepts about molecular structures, such as "carbon double bonds" that allow molecules to absorb specific wavelengths of light in the electromagnetic spectrum. Students lacking deep knowledge of organic chemistry and physics may find this explanation difficult. The absorption process at the molecular level, related to light wavelengths, is also confusing for students without accurate visualization. Therefore, this section needs simplification, utilizing analogies or more concrete visual representations.
3. Principles of Electromagnetic Radiation in the Batik Dyeing Process Explaining electromagnetic radiation involved in the batik dyeing process requires a basic understanding of light waves, wavelengths, and electron energy changes at the molecular level. These concepts, related to physics, may not be easily understood by students without an advanced background in physics or chemistry. Hence, this explanation needs simplification by replacing technical terms like "electromagnetic radiation" and "energy transitions" with more understandable language and providing analogies more accessible to students.
4. Redox Reactions in Dyeing Redox reactions are among the more abstract concepts, involving electron transfer between dyes and other chemicals. Students often find this process confusing as it involves atomic and electron changes at the molecular level. Explanations about how dye substances undergo oxidation and reduction changes in the dyeing process are highly technical and require a basic understanding of electrons and atomic interactions. Therefore, this section also requires simplification through the use of analogies and avoiding complex chemical terms like "electron transfer" and "oxidation changes."

The methods of didactic reduction for addressing the difficult contexts for students are summarized in Table 4 below.

Tabel 4. Didactic Reduction Process

No	Context	Description
1	Simplification of Complex Elements	The section explaining the detailed structure of fabric polymer and redox reactions at the molecular level is simplified by removing difficult technical terminologies.
2	Use of Visualization	Visualization is used to explain the principles of electromagnetic radiation and chromophore groups in batik dyeing.
3	Use of Analogy	Analogies are used to explain chromophore groups and electromagnetic radiation, such as comparing dye molecules to "keys" that "unlock" light and produce color.
4	Particularization	The batik dyeing process is broken down into smaller, easier-to-understand stages. Each step, from fabric dyeing to color fixation, is explained separately, focusing on how dye molecules bond with fabric fibers, making it comprehensible without deep chemical mechanisms.

Discussion

Context-based chemistry learning using Cirebon Batik integrates relevant chemistry concepts with a rich cultural process. Utilizing Cirebon Batik as a learning context aims to demonstrate that chemistry is not only confined to laboratories but also has practical applications in everyday life, particularly within Indonesian culture. However, although this topic is highly relevant and engaging, many chemistry concepts involved in batik-making, such as fabric polymerization, redox reactions, chromophore groups, and electromagnetic radiation, are often challenging for students to understand. Therefore, a didactic reduction approach is necessary to simplify the material and facilitate students' comprehension.

Using Cirebon Batik as a context for teaching chemistry reflects the principles of a context-based approach, which is highly valued in contemporary science education. This approach connects science to students' everyday experiences, creating more meaningful and relevant learning. Context-based education has proven effective in enhancing students' understanding because they can relate what they learn to the real world (Holbrook & Rannikmae, 2018). In this case, Cirebon Batik is not only a cultural artifact but also a medium for understanding the chemistry processes involved in batik-making, such as polymerization, molecular interactions, and redox reactions.

According to Chamberlain & Niven (2021), incorporating local cultural contexts into science education can enrich students' learning experiences and increase their engagement. Batik, as part of Indonesia's cultural heritage, provides profound value by strengthening the connection between science and culture and helping students understand that scientific knowledge has broader and more relevant applications in their everyday lives. Thus, context-based approaches like this are essential for linking chemical theories with cultural practices familiar to students.

Didactic reduction in chemistry learning based on Cirebon Batik aims to simplify complex chemistry concepts to match high school students' comprehension levels. Several chemistry concepts involved in batik-making, such as fabric polymer structures, chromophore groups, electromagnetic radiation, and redox reactions, require greater simplification to facilitate students' understanding. Anwar (2010) emphasized that didactic reduction is not merely about simplifying material but also presenting it in a relevant and easily understandable manner for students.

For example, in the topic of fabric polymerization, explanations about polymer structures composed of repeating monomers and complex chemical bonds are often too technical for students without basic knowledge of organic chemistry. Thus, the polymerization process can be explained more simply by describing fabric fibers as "long threads" that absorb dyes more effectively, avoiding terms like "monomer" and "covalent bonds," which are difficult for students to understand (Duit et al., 2012). This simplification enables students to grasp the basic concept without being overwhelmed by irrelevant technical details.

One of the most challenging parts for students to understand is the concept of chromophore groups in dyes and the electromagnetic radiation involved in batik dyeing. Chromophore groups are parts of dye molecules responsible for absorbing light and imparting color to substances (Clarke & Sowerby, 2016). Understanding how chromophores interact with light wavelengths to produce color requires in-depth knowledge of physics and chemistry, which is often too abstract for students without clear visualization.

Barnett & Hodson (2016) stated that visualization is critical in helping students comprehend abstract concepts like light-matter interactions. In this context, using diagrams or illustrations that depict how dye molecules absorb light and transform light energy into color on fabric greatly aids students in visualizing the process. Simplifying explanations about electromagnetic radiation involving wavelength and photon energy concepts using simple analogies, such as "light entering fabric like a key unlocking color," makes these concepts more understandable (Mason, 2018).

The concept of redox reactions is one of the most challenging chemistry topics for students, as it involves electron transfer between dyes and fabric fibers at the molecular level. Explanations about how dyes, initially colorless, change color after undergoing redox reactions often confuse students, especially when detailed changes in oxidation and reduction levels are included.

According to Carter et al. (2020), one way to simplify redox concepts is to reduce the complexity of explanations about electron and atom changes and use simpler analogies. For instance, describing redox reactions as "coloring that occurs when dye meets fabric and provides color through chemical reactions that change it" without delving into electron-level changes can help students focus more on the visual result (the color on the fabric) rather than the intricate chemical process.

The use of analogies and visualizations is key in didactic reduction. As explained by Palincsar (2019), appropriate analogies can help students relate new knowledge to their existing experiences, making abstract concepts more accessible and understandable. For example, describing chromophore groups as "keys" that unlock "locks" on fabric allows students to imagine the interaction between dyes and fabric fibers in a more comprehensible manner.

On the other hand, visualization plays an essential role in helping students see abstract chemical processes concretely. Diagrams or illustrations showing how dye molecules absorb light and how changes in molecular energy produce color can make difficult chemistry concepts more accessible (Swan et al., 2020). By illustrating the batik dyeing process step by step—such as dipping, color fixation, and drying—students can more easily follow and understand each stage of the process.

Context-based chemistry learning using Cirebon Batik with a didactic reduction approach significantly impacts students' understanding of complex chemistry concepts. By simplifying concepts such as fabric polymerization, chromophore groups, electromagnetic radiation, and redox reactions, and connecting them with relevant cultural contexts, students can more easily grasp the practical applications of chemistry in their lives. This supports the argument that context-based learning can enhance students' understanding and interest in chemistry while enriching their experience of linking science with culture (Chamberlain & Niven, 2021).

The implementation of didactic reduction in this learning also underscores the importance of delivering material that aligns with students' cognitive development, as explained by Bransford et al. (2019). By simplifying overly technical material and connecting it to students' everyday experiences, chemistry learning materials become not only easier to understand but also more meaningful. This leads to deeper and more sustainable learning, enabling students to apply chemistry concepts in broader and more relevant contexts in their lives.

4. CONCLUSION

Chemistry learning based on Cirebon Batik offers a rich and culturally relevant approach to students' lives. In this study, Cirebon Batik was used as a context to teach complex chemistry concepts, such as fabric polymerization, redox reactions, chromophore groups, and electromagnetic radiation. Although these topics are highly relevant and engaging, they are quite challenging for high school students to comprehend without proper simplification. Therefore, didactic reduction becomes a crucial step to simplify the material to align with students' cognitive levels.

The results of the comprehensibility test indicated that several sections of the text explaining redox reactions, fabric polymer structures, and electromagnetic radiation in batik dyeing require significant simplification. Overly technical concepts, such as electron changes in redox reactions and the interaction of light with dye molecules, were particularly confusing for students. Consequently, several didactic reduction methods were applied, including the removal of complex elements, the use of visualizations, the incorporation of analogies, and the particularization of material to facilitate students' understanding.

By simplifying the material through didactic reduction, chemistry learning based on Cirebon Batik becomes more comprehensible, engaging, and meaningful for students. This, in turn, can enhance their interest in and understanding of science.

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