Local Wisdom-based Contextual Learning as Embedded-STEM approach in High School Chemistry

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Abstract

The application of STEM in Indonesia can be made through an embedded approach using the social, cultural and technological contexts encountered by students daily. This study aimed to reconstruct the context of Cirebon local wisdom, i.e., batik, to be used as a context for embedded STEM chemistry learning in high school. This research used a qualitative method by choosing the Model of Educational Reconstruction (MER) as the research framework. In this study, observations were made on the batik-making process, a literature review to explore the batik context’s chemical perspective, and interviews to obtain information about students’ preconceptions about batik. The findings indicated that the essential components of batik (fabric, wax, and dye) and the process of batik making were inextricably linked to chemical processes. According to the literature review, the context of batik is connected to several high school chemistry concepts, including organic chemistry (particularly regarding aromatic derivatives and polymers), electromagnetic radiation, chemical bonds, acid-base, oxidation and reduction, and stoichiometry. Meanwhile, it is known from student interviews that students’ preconceptions about the scientific content of batik and related chemical concepts remain clearly distinguishable from their correct scientific conceptions. However, students expressed a favourable attitude toward the possibility of incorporating batik into chemistry instruction.

Keywords: contextual; local wisdom; embedded-STEM

How to cite this article:

INTRODUCTION

The trend of STEM education has developed over the last few decades in various countries from all over the world (Firman, 2016). The STEM approach in education can create students capable of solving problems in the 21st century (Anggraini and Huzaifah 2017). However, there are challenges to implementing the STEM approach in the education system. The curriculum structure should be designed to facilitate the principles of STEM education as outlined above. In Indonesia, the STEM approach is easier to apply at the elementary school level not also because the curriculum is thematically integrated, but also each level is taught by one teacher (Roberts, 2012). In another case with junior or senior high schools, the curriculum is not thematic (still separated between subjects), and a different teacher teaches each subject.

Changing the entire curriculum structure is not the best choice and is challenging to conduct. The most likely option for implementing STEM education without restructuring the curriculum is through an embedded or contextual STEM approach (Roberts, 2012; Syukri, M., Lilis, H., & Subahan, 2013). Through this approach, STEM education can be applied to individual subjects, including Chemistry subjects, without a context (functional, social or cultural) is needed to convey domain knowledge to students (Chen, 2001). For example, in Germany, the school curriculum is packaged with a contextual approach (Marks, Stuckey, Belova, & Eilks, 2014). It is in line with Suraphan and Yuenyong (2019) that the teaching approach of STEM education intersects with context-based learning. Thus, to develop STEM learning with a context-based approach, it is necessary to conduct studies related to the context used.

In this study, educational reconstruction was carried out in the context of the local wisdom of Cirebon, namely batik Cirebon, to serve as a context for STEM-embedded high school chemistry learning. The information obtained from this research are 1) the chemical perspective of the batik context, 2) students' preconceptions related to the batik context, and 3) the potential of the batik context to be used in STEM-embedded-based chemistry learning.

METHOD

This research was conducted with a qualitative method. The research framework used to guide this research is the Model of Educational Reconstruction (MER) created by Duit et al. (2012). This model is commonly used in educational reconstruction research on a relatively new science context in the school curriculum. MER components are 1) description and analysis of the scientific perspective, 2) research in the learning process, and 3) design and evaluation.

In this study, the first two stages of the MER component, as mentioned above, were carried out. The first stage of this research was carried out through direct observation of batik artisans and analysis of the chemical perspective of the batik context. Direct observations were made to traditional batik artisans, one of Indonesia’s leading batik showroom production sites. The batik fabrics produced there are all written batik. For comparison purposes, observations were also made to batik artisans who make batik more modern by using a stamp. The second process, namely the chemical perspective analysis of the batik context, was carried out through a literature review of three books and three articles related to batik and textile chemistry. The results of this literature review are in the form of chemical concepts related to the components and processes of batik making. The results of this analysis stage are then reduced in a didactic manner using Standar Isi Mata Pelajaran Kimia SMA Kurikulum 2013 as a reference. A map of the relationship between the context of batik and the chemical concepts inherent in it was obtained from this process.

The second stage was conducted through in-depth semi-structured interviews with 14 high school students in in 11th and 12th grade to explore their preconceptions of the context of batik and their knowledge, especially in the field of chemistry related to the context of batik. Respondents were selected through a purposive sampling approach by selecting students who could represent various groups of students based on their level of understanding ability (low to high). The purpose of sampling with this model is to explore as much information as possible about their preconceptions related to the context of batik and chemical concepts related to batik. The process of reconstructing education in the context of batik can facilitate all
groups of students. In this interview, there were three groups of questions from a total of 16 questions, namely: 1) STEM education knowledge (4 questions), 2) students’ preconceptions about chemical approach of batik (5 questions), and 3) respondents’ viewpoints on the use of batik as a context for STEM-based chemistry learning (3 questions) (7 questions).

At this stage, credibility and dependability tests are established using member check and expert judgment procedures (investigator triangulation), which are analogous to the methods used to assess validity and reliability in quantitative research. This procedure was followed to ensure three factors: content, language, and appearance. The inputs from experts on these tests have been used in the revision process of the final instrument.

Going to follow that, the data from this study were analyzed using Katmann’s hermeneutic method (1996). This analysis covers four essential points in the education reconstruction process. The first point is how scientific theory can explain the context of batik (components and the manufacturing process) and how it relates to high school chemistry concepts. The second point is whether there are any limitations in explaining the theory. The third point covers the social and ethical implications associated with this context. The fourth point relates to what application areas can take advantage of the context.

Table 1. Research instruments

<table>
<thead>
<tr>
<th>No</th>
<th>Research question</th>
<th>Instrument used</th>
<th>Data obtained</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Scientific perspectives on the batik Cirebon context and related chemical concepts</td>
<td>Table of batik context structure from scientific references analysis</td>
<td>Batik context manuscript</td>
</tr>
<tr>
<td>2</td>
<td>Chemical concept related to batik</td>
<td>Table of chemical concepts related to LED context analysis</td>
<td>Chemical concept related to batik manuscript</td>
</tr>
<tr>
<td>3</td>
<td>Students’ preconceptions about the context of batik and related chemical content</td>
<td>Interview guidelines</td>
<td>Students’ preconception map of batik and related chemical content</td>
</tr>
</tbody>
</table>

RESULTS AND DISCUSSION

Observation results

The three main components used in the batik-making process are:

- a. Fabric. The types of fabrics used in the batik-making process are: 1) natural fibres (mori, silk ATM and ATBM, doby, viscous rayon) that will work well with most of dyes and 2) synthetic fibres (polyester). Certain dyes are required for this type of fabric.

- b. Wax, gendorukem and vegetable oil. These materials are used in the nembok process to cover the base of the fabric that does not need to be dyed. The appropriate use of these three materials is determined by the circumstances. If a smooth motif is desired, gendorukem and vegetable oil should be added; however, if a rough/unsmooth motif is desired; only wax should be used.

- c. Dyes (napthol and indigosol) are the most critical component in manufacturing batik as a colour giver to batik cloth.

The first stage of making batik (especially *batik tulis*) is the tracing process or drawing motifs (traditional term is *anglengreng*). The cloth was spread on a glass table fitted with a printed motif and a lamp underneath. Then, the pattern tracing process was carried out using a 0.5 cm ballpoint pen. This tracing process requires special skills, flexible hand movements, to produce delicate patterns with smooth lines. Most types of fabric do not require special treatment, except for silk. The next stage is attaching the motif that has been drawn (another term *isen-isen*). This stage of the batik-making process takes the longest, depending on the density of the batik motif. This is accomplished by spreading the cloth across a wooden cross and then using melted wax in canting to cover the motif. After going through the *isen-isen*, the cloth is walled (covered with a base that does not need to be coloured) with wax. Then, proceed with the dyeing process, soaking the fabric in a dye solution according to the desired colour. The last stage is finishing, which brings out the desired colour by soaking the batik cloth in a specific solution. Then, the cloth is washed (*anggumbah*) and dried in the sun.

Chemical Perspective Analysis of Batik Context

In analyzing the chemical perspective of Cirebon batik, three central components were determined in the batik-making process, which
was examined for their scientific content, namely cloth, wax and batik dye. Below is an analysis of six references related to batik and textile chemistry.

Table 2. Chemical perspectives and related high school chemistry concepts of batik Cirebon

<table>
<thead>
<tr>
<th>Sub-context</th>
<th>Chemical perspective</th>
<th>High school chemistry concepts (based on KD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fabrics</td>
<td>Natural and synthetic fabrics are polymers composed of repeating monomers. Apart from carbon, hydrogen, and oxygen atoms, polymers typically contain constituents or other functional groups. The functional groups hydroxyl, carbonyl, carboxyl, amino, and ester are the most prevalent in fibre polymers. (Timár-Balázsy &amp; Eascop, 2012).</td>
<td>Polymer KD 3.11 and 4.11 (12th Grade)</td>
</tr>
<tr>
<td>Waxes</td>
<td>Wax is made up of esters of fatty acids and long-chain alcohols (Malik, Retno, &amp; Ayu, 2016). Waxes are hydrophobic, preventing dyes (which are water soluble and hydrophilic) from coming into contact with the fabric. Other basic waxes, such as resins to increase adhesiveness, paraffin to increase friability, and animal fat to increase liquidity, can be combined to produce desired wax characteristics (Unesco, 2009).</td>
<td>Alcohols and Leps KD 3.11 and 4.11 (12th Grade)</td>
</tr>
<tr>
<td>Certain dyes can only be used in certain fabrics</td>
<td>Polarity, secondary bonding (both intermolecular and intramolecular), pH, solubility, water affinity, and chemical intermolecular interaction</td>
<td>KD 4.7 (10th Grade)</td>
</tr>
</tbody>
</table>

### Colouring process

<table>
<thead>
<tr>
<th>Colouring process</th>
<th>Chemical bonding</th>
</tr>
</thead>
<tbody>
<tr>
<td>The dyeing process occurs when fabric molecules form chemical bonds with dye molecules (Timár-Balázsy &amp; Eascop, 2012). Dyes are organic compounds that contain a chromophoric system, a chemical structure that can absorb visible light selectively (Timár-Balázsy &amp; Eascop, 2012).</td>
<td>KD 3.5 (10th Grade)</td>
</tr>
</tbody>
</table>

### Chromophoric compound structure

<table>
<thead>
<tr>
<th>Chromophoric compound structure</th>
<th>Hydrocarbon (11th Grade)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A joint chromophoric compound contains a conjugated system in which carbon atoms alternately form single and double bonds. (Timár-Balázsy &amp; Eascop, 2012).</td>
<td>KD 3.1 and 4.1</td>
</tr>
</tbody>
</table>

### Reaction of coloring using naphthol

<table>
<thead>
<tr>
<th>Reaction of coloring using naphthol</th>
<th>Acid and base</th>
</tr>
</thead>
<tbody>
<tr>
<td>Two stages are involved in the process of dying batik with naphthol. The initial stage involves dyeing fabrics with a naphthol solution. At this point, no color is visible on the dyed fabric. The fabric is then dipped in a solution of diazodium salt to...</td>
<td>KD 3.10 and 4.10 (11th Grade)</td>
</tr>
<tr>
<td>Stoichiometry</td>
<td>KD 3.10 and 4.10 (10th Grade)</td>
</tr>
</tbody>
</table>
achieve the desired color in the second step. The initial stage of reaction:

\[
D - \text{OH} + \text{NaOH} \rightarrow D - O - Na
\]

The second stage reaction is:

\[
\begin{align*}
\text{NH}_2\text{Ar} + \text{HCl} + \text{NaNO}_2, 5^\circ \text{C} & \rightarrow \text{N} = \text{N} - \text{Cl} \\
\text{N} - \text{N} - \text{Cl} + \text{D} & \rightarrow \text{N} - \text{Na} \rightarrow \text{Ar} - N = \text{N} + \text{Cl}
\end{align*}
\]

(Chakraborty, 2010)

Indigosol is a watersoluble vat dye derivative. Indigosol is applied to the substrate in a soluble and reduced state, and then oxidized to the insoluble pigment's original state (Clark, 2011).

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**Figure 2.** Respondent's answers to the interview

In the question of the fabric aspect, the desired correct answer regarding the chemical concepts related to fabrics is a polymer. However, none of the respondents could answer correctly. The closest answer is respondent C, who gave the answer wool and polyester. However, the specific chemical concept of the answer appears/sounds. In fact, in high school chemistry books published by the Ministry of Education, the concept of polymers is clearly stated (Harnanto & Ruminten, 2009b; Utami, Saputro, Mahardiani, Yamtinah, & Mulyani, 2009b). Even fabric fibres are explicitly listed as examples of polymers. Thus, students’ difficulty in relating the polymer concept to the context of batik cloth comes from the student's intrinsic element.

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**Students' perspective on the chemical perspectives of batik Cirebon**

As mentioned above that STEM is embedded using everyday contexts in learning. It is necessary to translate and transform scientific content from the batik context into appropriate knowledge to be conveyed in classroom learning. This process, according to Niebert (2014) termed the reconstruction process. The scientific content, including batik Cirebon, is certainly not suitable for direct use in learning. The scientific content may have a depth of concept that is inappropriate or even absent in the high school curriculum. Therefore, the reconstruction process that involves the study of students’ perspectives is crucial. Niebert (2014) entions that the purpose of the student perspective analysis study aims to develop conceptual and pre-learning conceptions. Thus, in this study, regarding the MER, an analysis of student's perspectives on the scientific content related to batik and its relation to the high school chemistry concepts was carried out. Table 2 below shows the statistics of respondents’ answers from this interview process.

Students' perspective on the chemical perspectives of batik Cirebon As mentioned above that STEM is embedded using everyday contexts in learning. It is necessary to translate and transform scientific content from the batik context into appropriate knowledge to be conveyed in classroom learning. This process, according to Niebert (2014) termed the reconstruction process. The scientific content, including batik Cirebon, is certainly not suitable for direct use in learning. The scientific content may have a depth of concept that is inappropriate or even absent in the high school curriculum. Therefore, the reconstruction process that involves the study of students’ perspectives is crucial. Niebert (2014) entions that the purpose of the student perspective analysis study aims to develop conceptual and pre-learning conceptions. Thus, in this study, regarding the MER, an analysis of student's perspectives on the scientific content related to batik and its relation to the high school chemistry concepts was carried out. Table 2 below shows the statistics of respondents’ answers from this interview process.

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**Table 2.** Statistics of respondents’ answers from this interview process.

<table>
<thead>
<tr>
<th>Reaction of coloring using indigosol</th>
<th>Indigosol is a water-soluble vat dye derivative. Indigosol is applied to the substrate in a soluble and reduced state, and then oxidized to the insoluble pigment's original state (Clark, 2011).</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reaction of coloring using indigosol</td>
<td>Like naphthol, dyeing using indigosol does not directly give colour to the fabric. After dipping the fabric in an acidic solution (HCl or H_2SO_4) with the addition of sodium nitrite as an oxidizer, the color will appear. The oxidation process began with the hydrolysis of leuco vat dyes’ sulfonic esters, followed by oxidation to the parent dye to produce color. (Šrámek, 1963).</td>
</tr>
<tr>
<td>Redox reaction</td>
<td>Benzenes and its derivatives KD 3.10 and 4.10 (12th Grade)</td>
</tr>
<tr>
<td>Incorrect answer</td>
<td>Correct answer</td>
</tr>
<tr>
<td>Correct answer</td>
<td>Incorrect answer</td>
</tr>
<tr>
<td><img src="image" alt="Graph" /></td>
<td><img src="image" alt="Graph" /></td>
</tr>
</tbody>
</table>

*KD is an acronym for Kompetensi Dasar, or the essential competencies, that students must acquire as stated in the national curriculum.*

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of atomic structure (Buthelezi, Dingrando, Hainen, Wistrom, & Zike, 2008; Memurry & Fay, 2015; Silberberg, 2015). However, in the current structure of high school curriculum, this concept does not explicitly appear in the Content Standards for High School Chemistry. Consistent with the results of other studies, this concept is indeed not listed in most of these books (Harnanto & Ruminten, 2009a; Permana, 2009; Utami, Saputro, Mahardiani, Yantinah, & Mulyani, 2009a). There is only one book that contains a discussion of electromagnetic radiation (Ratna, Prasetyoko, Atmaja, Murwani, & Juwono, 2009). Thus, it is very likely that the teacher did not convey this concept. It may be the reason that none of the respondents answered correctly. Another thing that might be the cause, assuming the teacher conveys the concept, is the low level of students' connected conceptions on the topic of atomic structure as described in the study (Fadiawati, 2011).

Regarding the chemical structure of dyes, some respondents answered the set of questions correctly. In this question, the two most frequently used batik dyes, namely naphthol and indigosol, were asked about the similarity of the functional groups in the two batik dyes and what group of compounds these functional groups belonged to. The correct answer is the phenyl group and the benzene derivative compound. Most of the other respondents could not answer the question correctly because they were unfamiliar with relevant questions. They are fixated by the examples of compounds listed in the book and cannot apply the general concepts to the new compounds they see. It can be interpreted that students have not mastered the cognitive abilities of C-3.

Based on the three aspects explored above, there are two main conclusions related to students’ perspectives on chemical concepts related to the context of batik. First, most of the students’ perspectives are not following the correct scientific content. Second, the inappropriate perspective comes from factors such as intrinsic (low-connected conceptions of students, students’ cognitive abilities below C-3) and extrinsic (concepts not included in the SMA curriculum structure). Some study results show several alternatives learning designs to help improve students’ conceptual understanding, including using modelling and modelling skills (MMS), science heuristic writing (SWH), and other supporting media (Sudarmin, Sumarni, Mursiti, & Sumarti, 2020).

**Students’ interest in STEM learning using batik context**

In this section, students’ perspectives on STEM education, their enthusiasm in it, and respondents’ points of view on the use of batik context in STEM learning are explored. As with Katmann's scientific clarification of a learning context, the hermeneutic method is used to analyze the findings of this research (Katmann et al., 1996). This analysis would then look at the social implications of incorporating batik into high school chemistry STEM learning, the impact of that context on the field, and the high school chemistry concepts related to the batik-making process and their limitations in explanation. According to their responses, the majority of respondents initially had no idea what STEM education was. Their knowledge is limited to the acronym STEM. Following an introduction to STEM education, respondents are asked to identify the benefits and drawbacks of STEM education. Concerning the benefits of STEM education, the keywords that emerged from many respondents’ responses were developing critical thinking skills, solving problems (particularly those related to daily life), and being innovative. Meanwhile, respondents indicated that the lack of STEM education is complicated, time-consuming, and requires a more complex infrastructure than conventional learning. Thus, respondents are deemed to have a general understanding of STEM education. Concerning respondents’ interest in STEM education, 100% expressed an interest in participating in STEM education. The respondents cited a variety of reasons for their interest, including the following: 1) places an emphasis on academics, but can help students develop reasoning skills, think critically, and solve problems encountered on a daily basis; and 2) prepares students to learn in an integrated manner across multiple fields of study.

Additionally, respondents’ perspectives on the use of batik contexts in STEM learning were elicited, including 1) why batik contexts are appropriate for STEM learning, 2) non-chemistry STEM aspects associated with batik contexts, and 3) which themes (alternative dyes, environmental responsibility, or waste treatment) are most prominent to be raised in STEM learning. Students’ perspectives on why the batik context is an appropriate theme for STEM education vary. According to some
respondents, it is a matter of cultural preservation. Others tend to be viewed through the scopes of the environment, business, industry, and cultural arts.

Regarding other STEM aspects closely related to the context of batik, most of the respondents answered physics and biology as aspects that are closely related to that context besides Chemistry. Physics is related to the concept of pressure during making batik prints, and Biology is related to plants that can be used as an alternative to dyes. The aspects conveyed by the respondents are still included in the scientific aspect family. It means that respondents have not seen the interrelationships of other STEM aspects (technology, engineering and mathematics). The next question is about themes chosen from the batik context to be used as learning themes. Most of the respondents chose the theme of batik industry waste treatment, while others chose the alternative theme of environmentally friendly batik dyes.

According to the explanation above, it can be stated that respondents have a general understanding of STEM education's characteristics and a desire to experience STEM learning in the classroom. Concerning the context of batik, respondents believe that it can and should be used as a STEM learning theme. Several issues can be raised, including the processing of waste from the batik industry and the development of environmentally friendly dyes. Apart from the scientific aspect, the respondents were unable to establish a connection between the batik context's technological, engineering, and mathematical aspects. Thus, the subsequent learning design must enable students to practice identifying and determining the technological, engineering, and mathematical aspects of this context.

CONCLUSION

Educational reconstruction is required to advance STEM learning. A critical first step is to assess the scientific perspective on the situation at hand. The findings of this study indicate that the chemical perspective of batik is related to a number of high school chemistry concepts, including organic chemistry (particularly with respect to aromatic derivatives and polymers), electromagnetic radiation, chemical bonds, acid-base, redox, and stoichiometry. Another critical step is to analyze the perspectives of the students. The findings indicated that students' preconceptions about the chemical perspective of batik and related chemical concepts remained inconsistent with their scientific understandings. It is a result of both intrinsic and extrinsic factors affecting students (curriculum structure and learning support). These findings aid in determining the interventions necessary to facilitate the development of learning strategies. Despite this, students demonstrated a favorable attitude toward the possibility of incorporating batik contexts into chemistry learning. This demonstrates that STEM learning through batik can be developed and implemented in high school chemistry lessons.

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