Scientific content analysis of *batik Cirebon* and its potential for high school STEM-approached project-based instruction

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**Abstract.** The most likely STEM approach to be implemented in our curriculum is to embed social or cultural context on subject matter. *Batik Cirebon* is one of potential context to be used in STEM-approached chemistry instruction. Scientific content analysis of *batik Cirebon* is important to conduct for reconstructing the context so that it can be delivered properly to students. This study used Model of Educational Reconstruction design and the data were collected through literature studies of *batik Cirebon* and direct observation of *batik* craftsmen. The analysis of *batik Cirebon* scientific content structure was run based on hermeneutic-analytical method. The results of this study indicate that scientific perspective of *batik Cirebon* is related to many high school chemistry concepts: aromatic derivatives and polymer; electromagnetic radiation; chemical bonds; acid-base; redox and stoichiometry. The results of this study can be used for further research on the development of teaching materials and project-based learning using the embedded STEM approach using the *batik Cirebon* as a context.

1. Introduction

Education is now facing many challenges as consequences to the fourth industrial revolution (IR 4.0) which is happening all over the world. In this technology disruption era, education has become an inevitable part for other sectors success. Education system must be able to create human resources that master the 21st century skills, e.g. solving complex problems, critical thinking and creativity [1]. Science, Technology, Engineering and Mathematics (STEM) education is becoming a trend over the world as a solution to these challenges. Moreover, along with the increasing number of jobs in the sector of economic, science and technology, the need for human resources with a STEM background is also increasing over time [2].

STEM education trend itself is in line with our current national education demands. Research on STEM in Indonesia has been initiated since 2013 which focused on integrating STEM education in teaching and learning in primary and middle schools [3]. As stated by Roberts, implementing a fully integrated STEM curriculum is most easily conducted in primary schools because students are handled by a single teacher with a considerable time [4]. Meanwhile, high school curriculum is not integrated thematically. Each subject is taught by different teacher. Therefore, implementing integrated STEM in high school is more difficult than in primary school. Changing the current curriculum structure is not the best option to be taken. The most possible way to integrate STEM without restructuring curriculum is the embedded STEM approach [3,4]. In this approach, the domain of knowledge is acquired through problem solving techniques in social, cultural, functional contexts and also an emphasized through expert-like activities on real world situations [6]. Therefore, a lot of research is needed to analyze contexts in real world situations to emphasize domain knowledge in embedded STEM learning.
Developing learning material can be conducted on local context and cultural relativism [7]. In this study, the context used for the development of STEM-approached chemistry high school learning was batik Cirebon. In 2013 there are 530 small and medium industries and 4.408 workers in the batik industry [8]. This shows that both in terms of economic and socio-cultural aspects, batik industry have a large role for the people of Cirebon. Unfortunately, the batik industry also causes environmental issue due to its poor waste treatment. Several studies show that the water around the batik industry area is heavily polluted [7,8]. This environmental problem is potential to be developed into a STEM-approached chemistry high school problem-based learning. Although some research on batik has been done previously, the focus of those studies was emphasized on analyzing local plants as natural dyes, developing secondary metabolites as batik dyes and innovative skill profile in designing chemical batik motif [9,10,11]. In addition, those studies are conducted on college students as research subjects. Meanwhile, the idea of this research was to make the context of batik and its environmental problems as a theme for STEM learning in high school. This study was a preliminary study which aims to analyze the scientific content structure of the batik making process and examining its relationship to the concepts of high school chemistry. The result of this study will be used as references to determine in what chapters this learning is possible to be conducted, and also for developing a STEM-approached chemistry teaching material and project-based module.

2. Methods
This study was a descriptive qualitative research. Exploration of scientific content aspects of batik Cirebon context was conducted using Model of Educational Reconstruction (MER). This design is commonly used to reconstruct relatively new knowledge or innovative contexts in science that are not yet available in the school curriculum [13]. MER rests on two aspects: the scientific discipline aspect of content and its educational aspects, including student’s perspectives on a chosen subject and the design of its learning environment [14]. This study focused on the first aspect, which is exploring the structure of scientific content of the batik Cirebon making process including materials and tools used and the waste produced from each process. This process was carried out through literature studies of batik Cirebon and direct observation assisted by open interviews of reputable batik craftsmen in Trusmi, Cirebon. The analysis of batik Cirebon scientific content structure was run based on hermeneutic-analytical methods as described by Katmann as scientific clarification for a chosen context [15]. This analysis was including: 1) which are the scientific theories and concepts on high school Chemistry associated with batik making process, 2) where are their limitations in explaining batik making process, 3) which social and ethical implications are associated with those scientific concepts and theories and 4) which applicative field are affected from those scientific concepts and theories.

3. Result and Discussion
3.1. The process of making batik Cirebon
Observation was conducted towards batik craftsmen in Trusmi to explore the process of making batik Cirebon. There are three main components needed in the process of making batik: fabrics, waxes and dyes. Fabric used in the process of making batik can be composed of natural or synthetic fibers. Most dyes will work well on natural fibers, while synthetic fibers require certain dyes. Wax is used to block parts of the fabric that do not need to be colored or colored with other colors. There are many types of batik wax that can be used such as beeswax, gondonukem (residue of pine-gum distillation) and vegetable oils. The use of these materials depends on the desired blocking technique and the physical characteristics of the wax. Dyeing is the most important component in making batik. Common dyes used in the batik Cirebon making process are naphthol and indigosol.

The process of making batik consists of: (1) Anglengreng, batik pattern tracing on the fabric that has been cut. In this process, the fabric is stretched on a transparent table on which the bottom side has been installed the desired batik motif prints and lamps. (2) Isen-isen, application of wax designs to the fabric, using a traditional tool called a canting. This is the longest stage in the process of making batik, depending on the density of the batik pattern. In this process the fabric is spread on a wooden bar. Then the wax is heated and dripped out of the canting spout onto the fabric. (3) Nembok, process of
blocking part of fabric that will not be colored using wax to dry. (4) Ngobat, coloring process by dipping fabrics that has gone through nembock process in certain dye solution. (5) Finishing process consists of nglorod which is the process of removing wax from fabric by boiling it in hot water and drying batik fabrics that has been washed.

3.2. Scientific perspective and high school chemistry concepts related to the process of making batik

The content structure of the process of making batik is conducted through scientific perspectives analysis of the process of making batik from textbooks and journals. Below is a table that presents information about the scientific perspective of the process of making batik and its related high school chemistry concepts. National syllabus of chemistry high school is used as a reference to specify which high school chemistry concepts related to the scientific perspective of the process of making batik.

| Sub-context                              | Scientific perspective                                                                 | High school chemistry concepts (based on KD*) |
|------------------------------------------|----------------------------------------------------------------------------------------|---------------------------------------------|
| Fabrics                                  | Fabrics, both natural and synthetic, chemically are polymers consisting of repeating monomers. Apart from C, H and O atoms, polymers usually have constituents or other functional groups. The most common functional groups in fibre polymers are hydroxyl, carbonyl, carboxyl, amino, and ester [16] | Polymer KD 3.11 and 4.11 (12th Grade) Functional group KD 4.9 (12th Grade) |
| Waxes                                    | Wax is composed of ester fatty acid and long-chain alcohol compounds [17]. Waxes are hydrophobic so that they can block the contact of dyes (water-soluble, hydrophilic) with fabric. Other basic wax can be mixed to produce desired wax characteristics, like resins to make greater adhesiveness, paraffin for friability and animal fat to increase liquidity [18] | Alcohols and Lipids KD 3.11 and 4.11 (12th Grade) |
| Certain dyes can only be used in certain fabrics. | Functional group has a crucial role in determining polarity, secondary bonding (both intermolecular and intramolecular), pH, solubility, affinity to water, and chemical reactivity [16] | Intermolecular interaction KD 4.7 (10th Grade) |
| Colouring process                        | Colouring process occurs when molecules of fabric form chemical bonding with molecules of dye [16] | Chemical bonding KD 3.5 (10th Grade) Electromagnetic radiation KD 3.2 (10th Grade) |
| Chromophoric compound structure          | In a common chromophoric compound, a conjugated system is present, in which carbon atoms bind in single and double bond alternately [16] | Hydrocarbon (11th Grade) KD 3.1 and 4.1 |
| Naphthol                                 | Naphthol is an aromatic derivative compound. The molecular formula of naphthol is C10H8O. Naphthol is not soluble in water. To help dissolve naphthol in water, additional substances are needed, usually caustic soda or NaOH. The function of caustic soda is to convert naphthol into its naphtholato salt ion form so it can be soluble in water [19] | Benzene and its derivatives KD 3.10 and 4.10 (12th Grade) |
| Reaction of coloring using naphthol      | The process of dying batik using naphthol is through two stages. The first stage is dyeing fabrics in naphthol solution. At this stage, no color has been obtained on the dyed fabric. In the second step, the fabric is then dipped in a solution of diazodium salt to give the desired color. The first stage reaction: D-OH + NaOH → D - O - Na | Acid and base KD 3.10 and 4.10 (11th Grade) Stochiometry KD 3.10 and 4.10 (10th Grade) |
| Indigosol                                | Indigosol is water-soluble derivative vat dyes. Indigosol is applied to the substrate in a soluble and reduced form, and then oxidized to the original insoluble pigment [19] | Benzene and its derivatives KD 3.10 and 4.10 (12th Grade) |
| Reaction of coloring using indigosol     | Similar to naphthol, dyeing using indigosol does not directly give color to the fabric. The color will appear after the fabric is dipped in an acidic solution (HCl or H2SO4) with sodium nitrite added as an oxidizer. The oxidation process started with the hydrolysis of sulfaric esters of the leuco vat dyes then followed by oxidation to the original parent dye to produce color [21] | Redox reaction KD 3.9 and 4.9 (12th Grade) |

*KD is an abbreviation for Kompetensi Dasar or basic competencies that students need to achieve, provided in the national syllabus

As explained in Table 1, crucial aspects in the process of making batik are fabrics, waxes and dyes. Both interactions between fabrics-waxes and fabrics-dyes are the key of the process of making batik. The interaction might be in the form of covalent bonds, hydrogen bonds or London dispersion forces. Figure 1 show how fabric molecules interact with dye molecules. They form hydrogen bonds...
through hydrogen atom of the fabric and oxygen atom of the dye [16]. This interaction causes dyes adhere in the fabrics. Similar interaction occurs when waxes sticks to the fabric during isen-isen or nembok process.

![Figure 1](image1.png)

**Figure 1.** Hydrogen atom of the fabric and oxygen atom of the dye are forming hydrogen bond

In addition to its interactions, *batik* coloring also occurs because of the reaction of the dyes. In general, there are two types of dyes most widely used in the Cirebon *batik* industry, i.e. naphthol and indigosol [9]. Naphthol is insoluble compound. To make it solute in water, naphthol must go through a substitution reaction forming salt ion which is soluble in water [19]. Craftsmen use sodium hydroxide as substitution agent. The substitution reaction is described in Figure 2. When fabric is dipped in this solution, the color has not yet formed.

![Figure 2](image2.png)

**Figure 2.** Sodium hydroxide as a strong alkali substitutes H atom in hydroxyl group in naphthol with Na atom forming naphtholate salt ion that are more soluble in water

Fabric must be dipped in a solution of diazo dye to give desired color. The reaction can be found in Table 1. The solution must be reacted with acid before to form diazodium salt to ease the reaction between naphthol that already attached to fabric with the solution [22].

Meanwhile, *batik* coloring with indigosol provides different reaction mechanism. Indigosol is soluble to water, so the solubilisation reaction does not need to be done as in naphthol dye. Reaction of indigosol occurs through reduction-oxidation. The substitution reaction is described in Figure 3. Similar to napthol, dyeing using indigosol does not directly give color to the fabric. The oxidation process started with the hydrolysis of sulfuric esters of the leuco vat dyes (first reaction). Compound yielded from that reaction then oxidized by sodium nitrite to form the original parent producing color on the fabric [21].

The scientific perspectives of *batik* Cirebon cannot be automatically applied in high school learning. It is necessary to reconstruct the content structure so that the scientific perspective can be understood by students in accordance with their cognitive level [13]. Complex reactions and difficult theories are certainly not necessary to be delivered for high school students. But, in general, based on the analysis of the relationship between scientific perspectives of batik and high school chemical concepts in Table 1 above, it can be concluded that scientific content of *batik* Cirebon relates to many concepts of high school chemistry. Linking scheme between scientific content of making *batik* Cirebon with the concepts and theories of high school chemistry are shown in Figure 4 below.
Figure 3. Oxidation process of indogosol Yellow V. The reaction started with hydrolysis of sulfuric esters of the leuco vat dyes in acidic medium followed by oxidation to produce original parent dye.

From the result of this study, it can be concluded on what subject matter this learning is appropriate to convey. Referring to the common curriculum structure for high school, batik context will be properly addressed in organic compounds chapter at 12th grade of high school. This is based on two reasons: 1) the most dominant scientific perspective is related to organic compounds and 2) based on national curriculum structure of chemistry, students who are studying organic compounds have automatically been taught other chemistry concepts that related to the scientific content of batik.

Figure 4. Linking scheme between scientific content of batik with high school chemistry concepts.
4. Conclusion
Using batik as a context in learning chemistry giving consequences that exploration of the scientific structure related to batik making is important to conduct. This analysis is important for the reconstruction of the context of batik into material that can be delivered properly to students. The results of this study indicated that scientific perspective of batik is related to many high school chemistry concepts. The related concepts are: organic compounds especially aromatic derivatives and polymer; electromagnetic radiation; chemical bonds; acid-base; redox and stoichiometry. Referring to the dominant concepts related to the scientific perspective of making batik and the sequence of high school chemistry concepts in the national curriculum, context of batik can be applied properly to high school students on organic chemistry chapter. The results of this study can be used for further research on the development of teaching materials and project-based learning strategy using the embedded STEM approach using batik Cirebon as a context.

5. References
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