Literature review as a didactical content analysis: Sustainable magnetic lubricants based on ionic liquids

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Abstract. Magnetic lubricants are usually petroleum-based, but not renewable and cannot be environmentally degraded. It can cause the environmental problems. Magnetic lubricants based on ionic liquids can be environmentally friendly. The ionic liquid lubricants are synthesized from vegetable oil fatty acids, which is a locally sustainable and renewable sources. This molecular engineering can be used to integrate the concept of sustainability into teaching and learning. This study aimed to obtain the concept map and teaching learning sequence (TLS) from the scientist's conception. The method used is a qualitative content analysis (literature analysis type), using an instrument in the form of a content analysis format. The first phase begins with collecting literatures in the form of textbooks, monographs, review results and research articles. The next phase is descriptive analysis, selecting categories, and evaluating the material didactically. This research produces the concept map, TLS and clarified chemical concepts. The scientist's conception obtained is the application, function, characteristics of media magnetic lubricants, ionic liquids and examples of magnetic lubricants based on ionic liquids. Concept map and TLS can illustrate the relationship between one concept and another. They also show the relationship between science, technology and engineering. The results can be used as the basis for the preparation of teaching materials and didactical designs for teaching and learning.

1. Introduction
Magnetic media lubrication is critical to the reliability of magnetic recording systems or hard disk drives (HDDs) [1]. In conventional magnetic recording systems, thin film media require a lubricant which can be used to reduce friction and wear caused by contact between the magnetic read-write head and the metal disk [2]. Reduction of friction and wear by using lubricants allows the system to work without premature breakdown [3]. A good lubricant for magnetic media surfaces is a lubricant with materials that provide wear protection when the substrate surface is exposed to various environmental conditions (temperature, pressure, humidity). It is important that the lubricant remains on the surface of the media throughout the life of the file without degrading [2]. Lubricants needed for magnetic thin film media with low friction and wear are lubricants that have good thermal stability, non-volatile, non-flammable at high pressures, and have good viscosity in order to survive and protect the surface of the media. In addition, the lubricant must be strongly attached and not react with the surface of the media being lubricated and has environmentally friendly. Therefore, in choosing a good lubricant, the lubricant must have low surface tension, good surface affinity, inert to media, non-toxic and non-flammable, and soluble in organic solvents [4].

In general, magnetic lubricants are made from mineral oil with a petroleum base. However, these petroleum-containing products are limited in availability, toxic, and harmful to the environment[5]. Increasingly stringent regulations regarding the use, containment and disposal of petroleum-based...
lubricants, together with concerns arising from the depletion of crude oil reserves and the accompanying increase in oil prices, have increased interest in the development of environmentally friendly lubricants [5]. Although progress has been made in the development and application of natural oil-based lubricants, problems arising from the unsustainable nature of these materials make them a desirable alternative [6].

The proposed solution to this problem is the use of ionic liquids in lubricating magnetic media. Ionic liquids are molten salts at room temperature that can exhibit outstanding wear protection and significantly reduce friction [7]. Ionic fluids represent a new class of bio-lubricant that shows the potential to improve the limitations associated with conventional lubricants [6]. Ionic liquids are seen as a reasonable solution because they can be made environmentally friendly by having non-toxic cationic and anionic constituents which in the long run can lower production costs [8]. Ionic liquids can be modified and easily adapted to compositions that can provide the level of thermal oxidative stability and lubrication required for magnetic storage [9]. Thus, its physicochemical properties can be easily reproduced, using various available methods to produce ionic liquids from non-petroleum products. Finally, their ability to maintain and operate in a range of environmental conditions comparable to that of petroleum makes these lubricants an attractive alternative to most oil-based lubricants [10]. The lubricant used as a learning topic in this research is an ionic liquid synthesized from vegetable oil fatty acids, which are locally sustainable renewable sources. The lubricant to be used is ionic liquid from fatty imidazolium salts. This fatty imidazolium salt can be synthesized from fatty acids [11] so it is possible to obtain this salt from local renewable sources such as palm oil and other vegetable oils. This engineering can be used to integrate the concept of sustainability into learning.

Teaching Learning Sequences (TLS) is an intervention research activity and product, such as a traditional curriculum unit package, which includes well-researched teaching and learning activities that are empirically adapted to students’ reasoning. One of the distinguishing characteristics of TLS is connecting scientific perspectives with students [12]. Scientific perspectives related to the topic of ionic liquids as sustainable magnetic lubricants were collected and compiled into a consequence map. Consequence maps are different from simple concept maps. Consequence maps that incorporate socio-scientific problems followed by scientific concepts. The scientific concepts used are only concepts that play a role in socio-scientific decision making. [13]. Consequence maps will encourage students to think more deeply about reciprocity and cause and effect. Based on the background described above, this study aims to obtain a concept map and teaching learning sequence (TLS) from scientists' conceptions of sustainable magnetic lubricants based on ionic liquids.

2. Method

The method used in this study is qualitative content analysis [14] type of literature analysis [15]. The stages of qualitative content analysis can be seen in Figure 1.

![Figure 1. Qualitative content analysis stages [14]](image)

The first stage, begins with collecting materials to be analyzed in the form of textbooks, monographs, review articles and research articles. The next stage is to do a descriptive analysis on the sources that have been collected, by condensing extensive material into a summary [16]. The third stage is category selection, at this stage entering pedagogic and didactic aspects into the results of the analysis. The concepts that have been analyzed are also categorized based on Science, Technology and Engineering and also grouped by system [17]. The last stage is material evaluation, at this stage the results of the analysis that have been categorized are described in a concept map and TLS. More detailed steps regarding category selection and material evaluation can be seen in Figure 2.
The instrument in this study is the format used at the material collection and descriptive analysis stages. The instrument format at the material collection stage shows the titles of several sources along with the year of publication and the author is equipped with the code used in the analysis results. The instrument used in the descriptive analysis stage is a content analysis format that contains a summary of the results of the analysis.

3. Results and Discussion

3.1. Material Collection

Science content clarification refers to qualitative content analysis from reliable sources. Materials collected for concept analysis include textbooks, monographs, review articles and research articles. Sources of literature as material for analysis are presented in Table 3.

| Table 1. Literature Sources for Analysis |
|----------------------------------------|
| **Title** | **Author** | **Year** | **Code** |
| Discovery of a Magnetic Ionic Liquid [bmim]FeCl₄ | Satoshi Hayashi and Hiro-o Hamaguchi | 2004 | A |
| Tribological Performance of Environmentally Friendly Ionic Liquid Lubricants | CJ Reeves, S. Garvey, PL Menezes, M. Dietz, T. Jen, and MR Lovell | 2012 | B |
| Magnetic ionic liquids: synthesis, properties and Applications | E. Santosa, J. Albob and A. Irabien | 2014 | C |
| Magnetic ionic liquids in analytical sample preparation: A literature review | M. Sajid | 2019 | D |
| A Review of Ionic Liquid Lubricants | Anthony E. Somers, Patrick C. Howlett, Douglas R. MacFarlane and Maria Forsyth | 2013 | E |
| From curiosities to commodities: ionic liquids begin the transition | Davis Jr, JH, & Fox, PA | 2003 | F |
| Applications of Ionic Liquids in Science and Technology: Ionic Liquid Lubricant with Ammonium Salts for Magnetic Media | Hirofumi Kondo | 2011 | G |

3.2. Descriptive Analysis

After collecting literature sources, a descriptive analysis is then carried out by condensing broad material into a summary [16]. The results of the descriptive analysis are presented in Table 4.

| Table 2. Qualitative Content Analysis Magnetic Lubricants Based on Ionic Liquids |
|----------------------------------------|
| **Content** | **Analysis Results** |
| Magnetic Media Lubricant Characteristics | The intermolecular forces in magnetic lubricants cause magnetic lubricants to have the same characteristics as ionic liquids such as high viscosity, low vapor pressure, strong surface affinity, low surface tension, and high thermal stability meaning they are able to safely withstand the increased temperatures and pressures involved when high friction occurs [A]. Apart from the influence of intermolecular forces, the |
hydrophobic part (usually a long hydrocarbon chain) in the lubricant molecule makes the lubricant insoluble in water or corrosive media in the metal environment, so it is able to protect metal surfaces well and is environmentally friendly because it is non-toxic. Lubricant molecules that are non-polar can dissolve in organic solvents which are generally non-polar in nature and are based on the solubility rule “like dissolves like” [B]. In addition, magnetic media lubricants have magnetic properties so that they can stick firmly to the surface of the media. Magnetic ionic liquids are room temperature ionic liquids which have their own paramagnetic properties without the need to add magnetic particles. This paramagnetic property is induced by anions, cations or both. The most common paramagnetic ionic liquids are those containing transition metal or lanthanide complexes in their anionic structure [C]. Magnetic ionic liquids can be promising magnetic liquids, because the anions of magnetic ionic liquids contain magnetic centers (with single electron organic free radicals or metal ion complexes) which can respond to external magnetic fields, there by becoming magnets [D].

Ionic Liquid

Ionic liquids usually consist of large organic cations (such as imidazolium, ammonium or pyridinium) and organic or inorganic anions (such as BF₆, Cl or Br). Due to the large size of the molecule and the chemical nature of the anionic group, the charge on the ions in these salts usually diffuses. Due to the decrease in electrostatic forces between the anions and cations in this salt and its asymmetrical shape, it is difficult to form a regular crystalline structure, therefore it can be liquid at room temperature [E]. Ionic liquids have very interesting physicochemical properties including their low vapor pressure that can be neglected, non-flammable, high thermal stability, high conductivity, wide liquid affinity, and solvent properties for various substances [F]. Based on research, ionic liquids with ammonium cations and carboxylate anions which are hydrophilic show a lower coefficient of friction than PFPE lubricants and other conventional lubricants. There are 2 factors that can affect the coefficient of friction, namely good coverage and the strength of the interaction between the lubricant and the surface of the media [G].

Analysis the scientists’ conception of magnetic lubricants based on ionic liquids is focused on several contents such as the characteristics of magnetic lubricants and ionic liquids which are shown in Table 4. In addition, there are results of analysis regarding the application of magnetic lubricants, the function of magnetic lubricants, examples of magnetic lubricants based on ionic liquids, their synthesis and analysis which are not presented in this article.

3.3. Category Selection

The analysis results obtained are grouped into the categories of science, technology, and engineering so that the relationship between the three can be seen. In the science category, the blue color indicates the characteristics or properties of magnetic lubricants and ionic liquids which are influenced by the molecular structure of the lubricant. The technology category which is colored green indicates the function of magnetic lubricant to reduce friction and prevent wear which is applied to the magnetic recording system of an external hard disk, floppy disk, radio tape cassette, and other magnetic media. While the engineering category colored orange shows examples of magnetic lubricants based on ionic liquids, the synthesis of these lubricants from fatty acids sourced from renewable vegetable oils and methods for analyzing them [18] such as preventing environmental pollution, restoring the damaged environment, and using resources efficiently.

In addition, it is also categorized based on the system [17] namely magnetic lubricant as the core system, application of magnetic recording system as a sub-system of the desired use, function of magnetic lubricant to reduce friction and prevent wear as the desired aspect of the sub-system, characteristics of magnetic lubricant and ionic fluid as a sub-system of properties, for example,
magnetic-based lubricant Ionic fluid as a sub-system of the desired product, synthesis of magnetic lubricants and methods in analyzing it as a sub-system of the production process and sub-system of the relationship between science, technology, economics, and the environment underlies the topic of ionic fluid as a local renewable magnetic lubricant.

3.4. Material Evaluation

Result of clarified chemistry concepts are evaluated based on categories and relationships between concepts. Concept analysis results regarding magnetic lubricants based on ionic liquids are depicted in the form of concept maps and TLS as shown in Figure 3.

![Figure 1. Concept Map and TLS Magnetic Lubricants Based on Ionic Liquids](image-url)
Figure 3 explains that the topic of magnetic lubricants based on ionic liquids is discussed based on the relationship between applications, functions, characteristics of magnetic lubricants, characteristics of ionic liquids and examples of ionic liquid-based magnetic lubricants. TLS in Figure 3 is shown by the stages of the concept associated with the question, starting from stage 0 with the socio-economic-environmental problems of the Indonesian people in meeting the technological needs related to magnetic lubricants by paying attention to the sustainability aspect of the source.

4. Conclusion
This research produces concept maps, TLS and clarified chemical concepts. Clarified chemical concepts were obtained from the concept analysis process. The scientists' conceptions obtained are applications, functions, characteristics of magnetic lubricants, characteristics of ionic liquids, examples of magnetic lubricants based on ionic liquids, their synthesis and analysis. The previously obtained concepts are processed at the stage of category selection and material evaluation so that they are interconnected and become a concept map. TLS is found on the concept map, which is indicated by concept stages that are linked to questions, starting from stage 0 with socio-economic-environmental problems of the Indonesian people in meeting technological needs related to magnetic lubricants by paying attention to aspects of source sustainability.

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