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Nature of Science in the Teaching Materials about Chemistry of the Rare Earth Elements: Results from a Qualitative Content Analysis Study

RISNAWATI UMAR
MAN 4 Maluku Tengah, jln. Gunung Manangis Desa Rajawali Kecamatan Banda
Email: rishachir@gmail.com

AHMAD MUDZAKIR
Departemen Pendidikan Kimia, Universitas Pendidikan Indonesia, Jl. Dr. Setia Budhi No. 229, Bandung 40154, Indonesia
Email: *mudzakir.kimia@upi.edu

ABSTRAK

Understanding nature of science (NOS) is part of developing scientific literacy skills. There are seven aspects of NOS that are included; tentative, subjectivity, empirical, creative and imaginative, socio-cultural, diverse research methods and relationship between scientific theory & law. The purpose of this research is to gain the concept maps and teaching-learning sequences (TLS) from the views of scientists regarding to understanding of NOS on rare earth elements (REE) through Education for Sustainable Development (ESD) approach. The qualitative content analysis method was chosen in this study throughout the literature analysis based on books sources, review articles and research articles. The instrument avail of in this study was a content analysis format, which was portray descriptively to construct the understanding NOS of prospective chemistry teacher students. The outcome of the analysis are compiled in the form of concept maps and TLS with triangulation between researchers as a guarantee of validity. The results of the concept map and TLS that have been compiled show the relationship between the seven aspects of NOS which are integrated into REE learning materials. REE is known have unique properties based on the electron configuration but is increasingly difficult to find in nature, thus encouraging creativity to create renewable energy that can be recycled from electronic waste. The outcomes of this REE and NOS concept map and TLS are expected to be used to develop the design of REE teaching materials and didactic designs that are oriented ESD.

Kata Kunci: ***Nature of Sains (NOS); Rare Earth Elements (REE); Concept Map & TLS***

1. Introduction

Learning about the nature of science (NOS) is very crucial for prospective teachers for several reasons, because it can help science teachers evolve a profound, strong, and incorporated understanding of NOS in a way that it can have multiple functions and benefits. The teacher not only conveys to students the description of science and scientific practice according to history, philosophy, sociology, and psychology, but also conveys how to condition a strong inquiry learning environment as well as authentic scientific practice by applying an effective pedagogical approach [1]. One of the courses that can be taught through a pedagogical approach by including NOS content is the inorganic chemistry course. Inorganic chemistry is widely known as a branch of chemistry that studies the properties and characteristics of atoms in the periodic table of elements (except Carbon and Hydrogen, which are more widely discussed in organic chemistry). The material taught in inorganic chemistry in this research is the study of rare earth elements which are a classification of lanthanide. REE is a critical metal that is widely used in advanced technologies ranging from cell phones and televisions to LED light bulbs and wind turbines [2]. Currently, the study of REE is one of the topics that is being hotly discussed in various countries, due to its increasingly rare availability in nature and the increasing consumption of REE in the world market [3].

In general, there are two basic questions for an educator to teach NOS to their students. First; what is the essence of science? and second; what particulars of science should be taught and studied? [4]. Understanding of NOS is closely related to the development of students' scientific literacy. Based on research from the gauging of science learning outcomes at the international level organized by the Organization for Economic Cooperation and Development (OECD) on the Program for International Student Assessment (PISA), it is pointed out that the acquisition of scientific literacy scores of tutee in Indonesia is still relatively shallow [5]. The low scientific literacy of students is such part of the motivations for education staff to try to improve the quality of learning.

The REE material taught not only covers general aspects of understanding and electron configuration, but also includes how the process of increasing the amount of REE reprocess has the potential to play a key role in overcoming various of criticalities in the future as a form of continuing education [6]. Through this material, students' understanding of NOS can be built on how scientific research is accomplished, what types of lore are produced, and can use the knowledge they have for critical thinking [7]. In addition, students' ability to understand NOS will make students able to formulate arguments and make decisions according to global problems that occur [8]. On the other hand, the provision of understanding of NOS can certainly be given to prospective teachers through learning in college courses [9]. So that as prospective teachers, in the future they will be able to transfer what they get to their students at school.

The material on rare earth elements is closely related to issues of sustainable development and other policies in various sectors and is able to transcend existing disciplines [10]. The chemistry of rare earth elements is needed to understand how these elements are used and how their use will develop in the future in various industrial sectors [11]. Rare earth elements have a relationship with NOS learning which is learning that targets science issues, how it operates, and how experts work as a social band [12]. In the development of science, it can be seen that NOS learning has begun to be neglected, even though NOS learning is the group of the most important things to be included in the upskill and learnedness process in the classroom [13]. NOS itself is an important element of science education and has been defended with good reasons so that it is embraced in the science subject at schools [14]. The topics contained an

inorganic materials for undergraduate students in chemistry learning are very diverse, such as the chemistry of inorganic elements which are the focus of research by chemists [15].

2. Method

This investigation uses a descritive content analysis research approach. The purpose of this research is to collect information about the extent interpretation of Nature of Science (NOS) in the undergraduates of the Faculty of Teacher Training and Education, the chemical education study program at Pattimura University, Ambon. This exploration was handled through the provision of interview sheets involving 28 students in the fourth semester. In this process, the researcher acts as an interviewer to gather information about the extent to which prospective chemistry teacher students understand NOS. The questions in the interview sheets were prepared by researchers based on 7 aspects of NOS which were adapted to rare earth elements. The step in qualitative content analysis can be seeable in Figure 1 below:

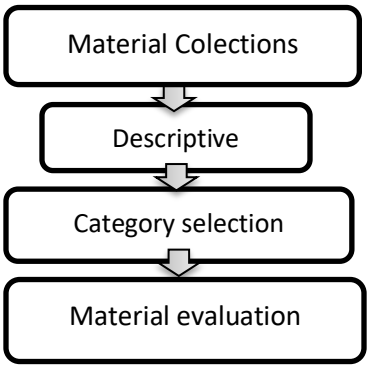

Figure 1. The process of Qualitative content analysis stages [17]

Several stages were carried out in this research, first; process of collecting and filtering data for analysis, through text books, review articles and research articles. Second; the researchers conducted a descriptive analysis as a step to get the gist or summary from the existing books and articles. Third stage is makes coding based on category selection. At this stage, the results obtained are based on content analysis which is rearranged to incorporate pedagogic and didactic aspects into the content. The last step in qualitative content analysis is material evaluation. The material evaluation step is the leg where the researcher reviews the material at the beginning and at the end, and makes a translation of the material into a structured concept map and TLS. The flow scheme in this study can be seen in Figure 2 below.

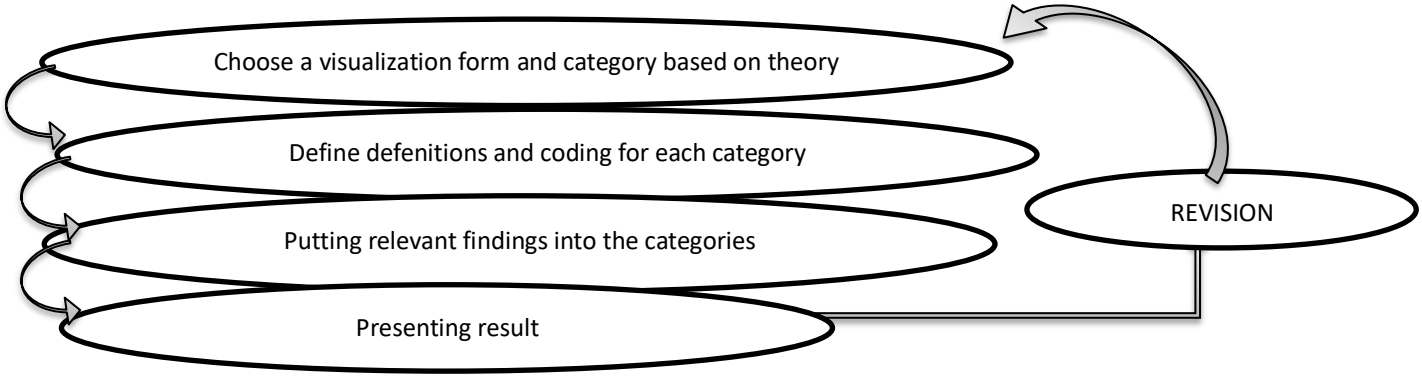

Figure 2. Process content analysis results [17]

1. Result and Discussion

3.1 Material Collection

The earliest step in this study is collection of various types of literature from various available sources. These literary sources include handbooks, monographs, review articles and scientific papers. The literature obtained from these various sources is then analyzed as study material and a reference source in research. The outcome of the literature collection can be observable in table 1 below.

Table 1. Literature Used for Content Analysis

Title	Writer	Year	Code
Examining Education Students ' Nature of Science (NOS) Views	**Celeste T. Mercado, Frienzky B. Macayana , Lorna G. Urbiztondo**	**2015**	**A**
The "General Aspects" Conceptualization as a Pragmatic and Effective Means to Introducing Students to Nature of Science	**Kostas Kampourakis**	**2015**	**B**
Students' understandings of nature of science and their arguments in the context of four socioscientific issue	**Rola Khishfe, Fahad S. Alshaya, Saouma BouJaoude, Nasser Mansour & Khalid I. Alrudiyan**	**2017**	**C**
Reconceptualizing the Nature of Science for Science Education	**Zoubeida R. Dagher, Sibel Erduran**	**2016**	**D**
History of Science (HOS) as a Vehicle to Communicate Aspects of Nature of Science (NOS)	**Nouri, N., & McComas, W. F.**	**2019**	**E**
Rare earth elements: A review of applications, occurrence, exploration, analysis, recycling, and environmental impact	**V. Balaram**	**2019**	**F**
Rare Earth Elements: Industrial Applications and Economic Dependency of Europe	**Georgios Charalampides, Konstantinos I. Vatalis, Baklavaridis Apostoplos, Benetis Ploutarch-Nikolas**	**2015**	**G**
Rare earth elements: Development, sustainability and policy issues	**Julie Michelle Klinger**	**2017**	**H**
THE RARE EARTH ELEMENTS: Fundamentals and Applications	**David A. Atwood**	**2012**	**I**

The Rare Earth Elements An Introduction	**J.H.L. Voncken**	**2015**	**J**
Curriculum Framework Education for Sustainable Development	**Jörg-Robert Schreiber and Hannes Siege**	**2016**	**K**
Education for Sustainable Development in Further Education	**Denise Summers and Roger Cutting**	**2016**	**L**

Descriptive Analysis

In descriptive analysis stage, the authors analyze each source from the various literatures that have been collected. The upshots of the descriptive analysis are outlined in table 2 below. certainty essential

Table 2. Content Analysis Result

Content	Analysis Result
Nature Of Science (NOS)	NOS is the convergence of a collection from knowledge which is very useful for developing scientific literacy. NOS refers to epistemology and sociology as a way of understanding, the certainty essential in scientific knowledge, grasp, social norms, the tier of knowledge and how expert manage scientific research (A). Understanding NOS can directly contribute to the development of scientific literacy (B). General aspects of NOS include (1) tentative (subject to change), (2) subjective (influenced) by the backdrop and proficiency of chemist), (3) empirical (based on and/or arise from surveying of nature), (4) creative and imaginative and (5) Social Context. Two extra aspects contain (6) the distinction between observation and inference and (7) the difference among hypotheses and regulation (C). NOS is more concerned with how to build epistemological understanding and knowledge as a scientific process (D). So it becomes very important for a prospective chemistry teacher to apply NOS into learning (E).
Rare Earth Elements (REE)	The rare earth elements are a batch of 17 chemical elements in the periodic chart of elements, specifically the 15 lanthanide element bands along with yttrium and scandium (F). REE is a non-essential which has a total consumption of 59% worldwide (G). REE has exceptional magnetic and conductive properties, enabling contemporary living hardware to be faster, lighter and more powerful (H). The rare earth elements are f-block elements, of which Scandium and yttrium belong to this group because they have similar ionic radii (I). REE is found in minerals, the main ores for REE are monazite, bastnaesite, and xenotime (J).
Education For Sustainable Development (ESD)	Education for Sustainable Development (ESD) is an effort to help implement national strategies that are incorporated into learning in schools. ESD is a UNESCO Global Action Program with the main goal of sustainable development (SDGs) (K). Factors causing environmental damage are exacerbated by increasing economic inequality in the population which makes the future of nature look even more bleak (L).

Table 2 contains scientists' assumptions related to the importance of understanding NOS for students as part of efforts to increase scientific literacy. The topics contained in inorganic materials for prospective chemistry teacher students are very diverse, such as the chemistry of metal elements studied in the fourth semester for FKIP students of UNPATTI chemistry education study program. The problem of REE is included in the learning by integrating the relevant sub-materials. So that the sustainability values contained in ESD can be integrated into chemistry learning.

3.2 Group Selection

The grouping of the outcomes of the evaluation was carried out to integrate seven aspects of NOS and continuing education into learning on REE. The content studied in this study is in the form of rare earth element chemistry teaching materials and their relationship to environmental sustainability values.

3.3 Material Evaluation

The elaboration of the results of the findings from the existing concepts is evaluated based on the categories and relationships between the concepts that are built. The concept of understanding NOS which is integrated into REE material based on sustainability values, is described in the form of a concept map and TLS can be viewed in picture 3.

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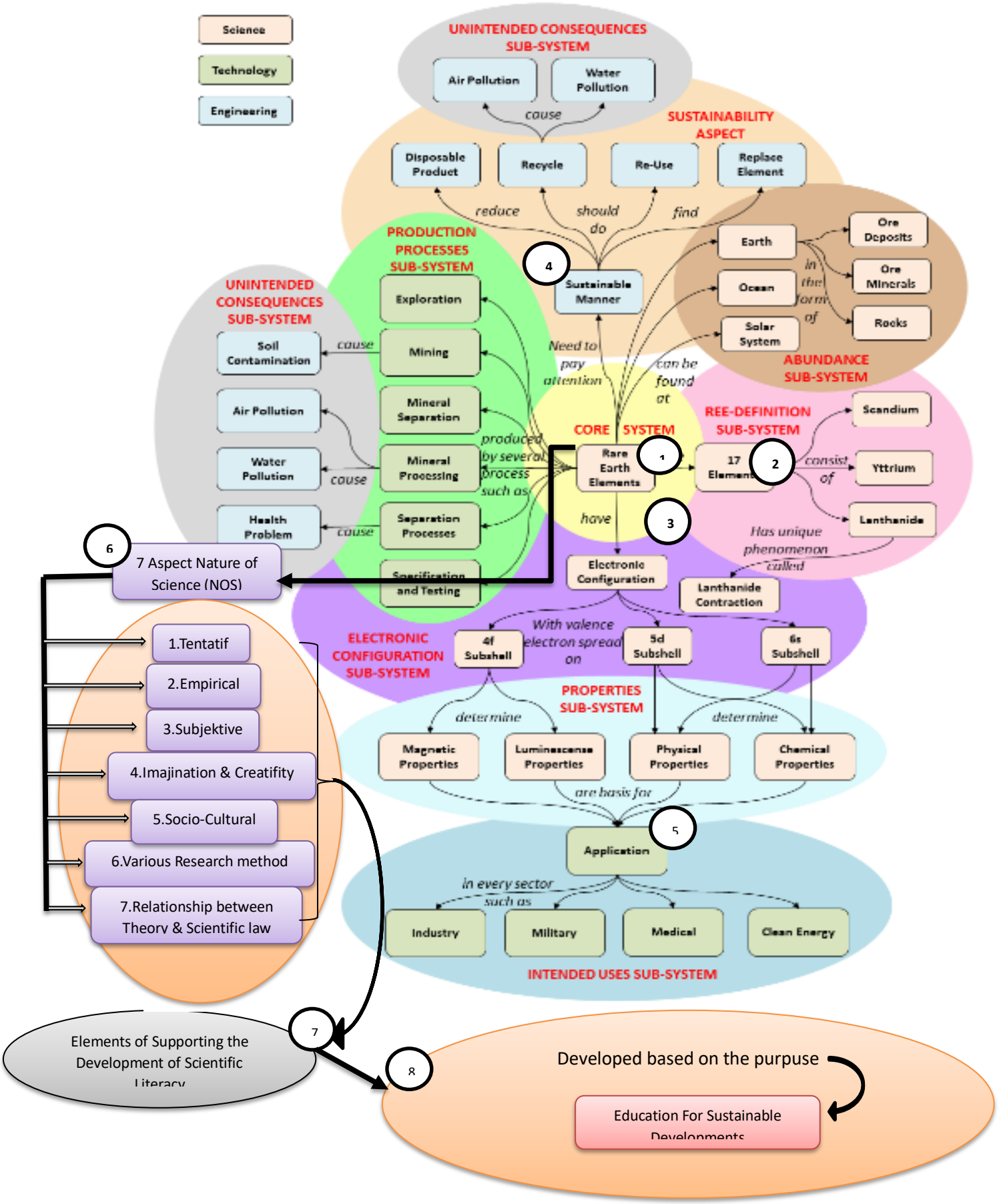

Figure 3 is a concept map and adaptation of TLS SOCME that has been developed by previous researchers, namely Pinasti, Titen. et al, 2021 submitted to ICMScE (19), then the researcher incorporate 7 aspects of NOS into learning on the concept map and TLS.

4. Conclusion

Every student is expected to have a grasp of nature of science that can be applied to everyday life as a result of the learnedness activity in the study hall. Strengthening the understanding of NOS on REE material is expected to be able to answer the challenges of the times regarding the advancement of science and technology in increasing students' scientific literacy. This development can be in the form of students' ability to think critically about existing problems, be creative in building concepts to find new things and be able to integrate sustainability values in their daily lives. According to the results of data processing, in this study, it can be found that in general content analysis Can be achieved through four steps; the literature assortment stage, descriptive analysis, category type and evaluation stage. Overall, it can be concluded that through qualitative content analysis it is proven that understanding of NOS can be built through strengthening the rare earth element chemistry. So as a further development step, the researcher hopes that the analysis in this course can be harnessed as a reference essential for compiling learning resources and making didactic designs.

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