The analysis of content teaching materials: identification of potential for developing systems thinking skills in coordination chemistry

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Abstract. The purpose of this study is to analyze the content of the coordination chemistry teaching materials used by lecturers in chemistry undergraduate students education program at one of Islamic University in Cirebon. It should has a potential for the development of students’ systems thinking skills. The data used in form of teaching materials compiled by a team of lecturers and digital textbooks that consist of complex coordination compound matter. This study uses the Model of Educational Reconstruction (MER) limited to only phase one namely content structure analysis. Then the qualitative content analysis (QCA) of the Mayring model has been applied. The first stage of MER content analysis is carried out namely clarifying the conception of the material from scientists. The result of the qualitative contents analysis of coordination chemistry teaching materials used by the lecturers meet the criteria of indicators to develop students’ system thinking skills. The structure of the contents of this teaching material showed that in each part of the key concepts represent the ability to identify, organize, map the concepts involved in coordination compound bonds and analyze, predict the structure of coordination compounds. It has been found that 88.89% of teaching material has potential to develop all indicator of student’s system thinking. The result showed that the content of coordination chemistry teaching materials has an influence in developing students' systems thinking skills.

1. Introduction
Teaching material is an important component for students, because teaching material is very supportive in the optimal learning process so that student understanding can be achieved well [1,2]. Good teaching materials are those that pay attention to which concepts should be emphasized in the concept of student systems thinking in order to achieve a comprehensive and scientific understanding [3]. However, most of the teaching materials available in the field show that the development of teaching materials that are prepared does not pay attention to the initial concept emphasis, the concepts interrelationship, and the implementation after study. Moreover, these teaching materials do not bring students to systems thinking. It is therefore expected that teaching materials compiled by the development team can include material concepts that are systematic, easy to understand and direct students to systems thinking [4].
Science learning has international standards that can be used as a reference for schools throughout the world such as the National Research Council (NRC), Next Generation Standards (NGSS), and the National Science Teaching Association (NSTA) to propose a system approach as an alternative of green chemistry to teach science content. Nature of Science (NOS) can be used as a systems approach as an effort to understand the truth of science as part of complex system phenomena [5]. Through a systems approach, scientific products obtained through scientific observation, practicum or research, which are described as part of scientific truth. It is needed the interrelationship of the interaction and the reciprocal process with each element in the system to holistically understand the truth of science.

Meanwhile, NRC and NSTA emphasize chemistry learning on the basic principles of green chemistry which are oriented to education sustainable development goals (SDGs). Another thing that is the originality and novelty of this research is the indicator of system thinking, that is developed and the measurement of the level of reasoning of students towards their system thinking skills.

Systems thinking teaches students to think about systems or components that build a complex of content [6,7]. Teaching the coordination chemical content as part of a system becomes something important to learn, because it has the character of systems thinking. There are identifying component in a system, explaining the function of each component in a system, the relation among them and explaining the relation between the system and other systems, analyzing the structure of coordination compounds and predict from a structure of coordination compounds. The system thinking has three types of groups, including cybernetic systems thinking, General System Theory (GST), and dynamic systems thinking [8].

Nowadays Inorganic Chemistry lecturers at the Islamic University Cirebon carry out using teaching materials compiled by a team of lecturers. One of the compiled teaching materials is in the form of a complex coordination compound material content. So far, content analysis has not been carried out related to the content analysis, but it should be the content that has the potential to develop students' systems thinking skills [9].

Using the system as basic for the development of programs and the syntax of chemistry lectures, in this case the ability to think systems needed in learning science. Therefore it is very important in doing analysis in this study, to be known whether the content of coordination compound materials used can develop students' systems thinking skills.

2. Methods
The method used in this study is a qualitative content analysis adapting the Mayring model [10]. The aim is to analyze the content of teaching materials used by lecturers whether they have the potential to develop students' systems thinking skills. The design of this study applies the Model of educational reconstruction that consists of three stages, e.i. (1) clarification of science conceptions; (2) investigation in students' conceptions; and (3) developing teaching-learning sequences as described. However, this research has been conducted the first stage only. The subjects in this study were students’ system thinking indicators, textbooks of coordination compounds of inorganic chemistry, and other international science learning standards using MER as described in figure 1.

This research procedure can be explained that qualitative content analysis with inductive-heuristic approach [10,11]. Qualitative content analysis is carried out on teaching materials used by lecturers, starting with reading the chemistry of coordination materials on teaching materials of lecturers’ teams and digital books on each line by line of the contents of teaching materials. It is important to check whether the teaching material is already compatible with the competencies of the course to achieve. Material that is not suitable can be reduced or repair. All content analysis has done with the same and repeated rules. In the next step, following the rules summarizes the analysis of qualitative content, and discusses the results and decides which content is adequate based on the competencies achieved. Furthermore, it provides an interpretation of the conclusions that lead to the research questions.
3. Result and Discussion

3.1. Analysis of contents of chemistry coordination complex teaching materials

Lecturers use several references in giving complex coordination chemistry course, including textbooks prepared by Chemistry Education Teaching Team the Islamic University at Cirebon, a text-book entitled "Essentials of Coordination Chemistry" as a supplementary material. Both teaching materials used together, then to find out the depth of the material analyzed as table 1.

Table 1. Analysis of contents teaching materials coordination chemistry

| Coordination Chemistry | Textbook 1 | Textbook 2 | Combined Materials (CM) of Textbook 1 & 2 |
|------------------------|------------|------------|----------------------------------------|
| Source: Coordination Chemistry | Source: Essentials of Coordination Chemistry | Source: Coordination Chemistry & Essentials of Coordination Chemistry combined |
| Author: UMC Lecturer Team | Author: Vasishta Bhatt | Materials (CM) |
| Crystal field stabilization energy (CFSE): energy difference between orbitals t_{2g} and e_{g} as the energy level t_{2g} is 4 Dq relative to the center of gravity and the energy level e_{g} is 6 Dq relative to the center of gravity. | Isomers in coordination complex compounds are classified into 2 types structural isomers and stereoisomers. Structural isomers divided into 10 isomers. | (CM1) Coordination compounds: compounds that contain one or more coordinating covalent bonds, which consist of metal atoms or a group of atoms surrounded by a number of neutral anions or molecules. |
| Crystal field stabilization energy (CFSE): energy difference between orbitals t_{2g} and e_{g} as the energy level t_{2g} is 4 Dq relative to the center of gravity and the energy level e_{g} is 6 Dq relative to the center of gravity. | | (CM2) Isomers in coordination complex compounds of the types of isomerization that occur in coordination complex compounds are classified into 2 types: structural isomers and stereoisomers. Structural isomers divided into 10 isomers. |
| Crystal field stabilization energy (CFSE): energy difference between orbitals t_{2g} and e_{g} as the energy level t_{2g} is 4 Dq relative to the center of gravity and the energy level e_{g} is 6 Dq relative to the center of gravity. | | (CM3) VBT: bonds in complexes are covalent bonds of coordination between overlapping ligands'orbitals containing free electron pairs with empty metal ion orbital, and be seen as Lewis acid-base reactions. |
| Molecular Orbital Theory (MOT): This theory considers electrostatic interactions and covalent interactions between the central atom and the ligands. | | |
Each teaching material analyzed in each sub-complex coordination chemical material, therefore eight sub-materials are obtained. The results of the analysis of each book then combined to produce large material that given to students.

3.2. Analysis content of teaching materials of complex coordination chemical using inductive-heuristic approach

The combined material analyzed qualitative content using the Mayring model with an inductive-heuristic approach, the results can be seen in table 2.

Table 2. Qualitative content analysis using inductive-heuristic approach

| Combined Text Materials | Clarified key concept on Coordination Compounds | Systems Thinking Indicator (I) |
|-------------------------|-----------------------------------------------|-------------------------------|
| CM1                     | In the context of this sub material describes in detail the parts in the complex compound coordination. Further explanation that the formation of coordination compounds due to the coordination covalent bonds between metal atoms and ligands. | • 11(identifying the components and process in the system). |
| CM2                     | In the context of this sub material explained that the coordination complex compound has an isomer. | • 12(Identifying the structure and function relationships between system components at one level organization). |
| CM3                     | In the context of the VBT sub-material the most important key concept is the overlap between the ligand orbitals containing the lone pair of electrons and the empty metal ion orbitals. | • 11(Identifying the components and process in the system). |
| CM4                     | In the context of sub material VBT weaknesses the most important key concept is the nature of magnetism cannot be explained, and the colour and stability of a complex compound cannot be explained. | • 13(mapping the concept of coordination compound at a specific level) |
| CM5                     | In the context of the CFT sub material the most important key concept is the interaction between the central ion and the ligand is the electrostatic interaction, and explains the difference between the spectrum of metal ions from the complex | • 14(analyzing concept relationships in one level with one level above or one level below). |
| CM6                     | In the context of the sub material CFT weaknesses the most important key concept is to assume the interaction between the central ion and its ligands only is an electrostatic interaction. | • 15(organizing system components, processes and interactions among them in the system framework) |
| CM7                     | In the context of the CFSE sub material the most important key concept is the level of difference between the $t_{2g}$ orbital energies and orbitals $e_c$. | • 18(predicting /reproducing of arising of system intervention - the loss or increase - of system components, using modeling or patterns that have been designed previously). |
| CM8                     | In the context of the MOT sub-material, the most important key concept is that increase in the energy level of each of their orbitals, so that they have bonding orbitals and anti-bonding orbitals. | • 17(able to make generalizations from patterns formed by the system) |

The calculation results show that 88.89% of the structure of the content of the material in teaching materials meets criteria of the students’ system thinking indicators. Each section of content of the teaching materials represents ability to identify, organize, map the concepts involved in the coordination of compound bonds, as well as analyze, predict from a structure of coordination compounds. While
11.11% of the content structure in teaching materials, did not represent the development of students' ability to think systems. Indicators of students' system thinking have not described in teaching materials including designing, developing models, and implementing prediction results. Therefore needs some improvement in the teaching material to achieve all indicators in optimizing the ability to students’ system thinking.

The coordination complex chemistry matter will be an important component in the lecture process for students to have provision in their systems thinking. Systems thinking is very important for students to be able to analyze, organize, predict and implement the prediction results from the concept, in order to provide benefits for the lives of students and society in general [12,13,14]. This is in line with one of the United Nations programs that is being implemented, which is related to sustainable development to increase quality education programs, especially in chemistry which is oriented towards green chemistry for a good climate [15]. Therefore it is important to have a system thinking from the beginning students.

The content material in the coordination chemistry teaching must designed by the team chemistry lecturers in Islamic University at Cirebon that could shows students' systems thinking abilities. There is still a need to improve and add concepts that do not yet reach the other system thinking indicators in the teaching material.

4. Conclusion
The first stage of Model of Educational Reconstruction (MER) adopted to clarify the concept of specific coordination chemistry and structure of content based on scientists. The scientists pour their scientific concepts through teaching materials. Based on the results and discussion, it concluded that the teaching materials of coordination chemistry used by lecturers in the first stage of MER at one Islamic university in Cirebon could develop students’ system thinking skills. Systems thinking skills are higher order thinking skills related to analyzing, synthesizing, predicting, critical thinking, solving the problems needed for students to connect facts, data, and scientific products learned, therefore their perceptions are in accordance with the explanations of scientists.

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