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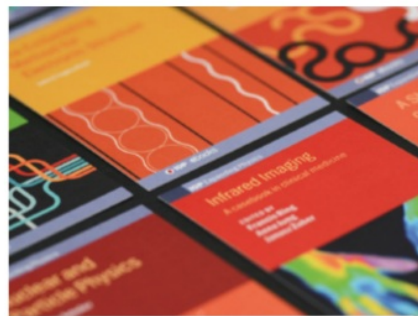
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Understanding of chemical content in high school: difficulties from the teacher's perspective

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Abstract. This research is trying to uncover the difficulties encountered by high school chemistry teachers in teaching chemical content. A total of 30 chemistry teachers who were attending a regional teacher professional development program at the Institutes of Educational Development in Central Java were included in this study. The methods of collecting data by using questionnaires and interviews to respondents. The results showed that the difficulty of teaching chemical content experienced by 30 chemistry teachers from all over Indonesia was mainly due to the lack of knowledge of chemistry mastered both in the macroscopic, microscopic and symbolic aspects, the many concepts that must be mastered that were not interconnected, the low mathematical abilities of the teachers. The difficulties experienced by teachers are exacerbated by the difficulty of teachers to access various information and opportunities to participate in continuous professional development activities.

1. Introduction

Chemistry is one of components in the secondary school curriculum that supports students' intellectual development through a search to support nature and its transformation. Chemistry in secondary education provides opportunities for students to have a deeper global awareness and to help them learn important concepts, because Chemistry is considered a core science that can penetrate various fields of knowledge, such as engineering, health, astronomy, biology, and geology.

Unfortunately, in Indonesia – or even the world – the word 'chemical' has universal bad connotations. Often we hear about "chemical free" products, food "without chemicals", "chemical weapons". If you hear the word 'chemistry', public opinion automatically associates it with the word "dangerous", "denies", and damages the effects it has on humans or the environment. Chemicals are generally considered as an artificial materials, source of environmental and ecological damage, and potential damage by industrial contamination. Chemistry also has a bad image among students. Although chemistry has many benefits in human life, most students do not appreciate chemical development in various parts of us such as technology, health, agriculture, energy, etc. which benefits society.

School is the best place to build knowledge and broaden views about what chemistry and chemical products are. In the classroom; teachers and students are involved in developing skills and competencies that are important for student education. Chemistry begins to be taught as a separate subject since students enter the tenth grade of high school /vocational school, as part of a science curriculum, which includes biology, chemistry and physics. Chemistry can be seen at least at three levels: "There are levels where we can see and handle material, and describe their nature in terms of density, flammability, color, etc. This level we call the macroscopic level (real world). Second level commonly called symbolic level is the representational level at which we try to represent chemicals with their formulas and changes with equations. This symbol or symbol is part of the language. The third level is the atomic and molecular world (sub-microscopic level). very small ones that can atoms, electrons, molecules, and ions. The world of atoms is so small that we cannot use the senses to

observe them, therefore chemists explain it by using symbols / symbols in the form of numbers, models, and letters as the level of representation second [1].

These three levels are related, so that students' knowledge at each of these levels is very important for understanding chemical processes. Those where sometimes students attribute macroscopic properties to particles, sometimes also mixing two different levels of knowledge. Thus, the learning carried out by the teacher, often starting from the world of atoms (sub-microscopic) continues into the real world (macroscopic), but it can begin with the real world (macroscopic), usually by observing a phenomenon first, then leading to theory or models.

Chemical content studied by high school/ vocational students includes atomic theory, periodic system elements, chemical bonds, stoichiometry, reaction rates, chemical equilibrium, thermochemistry, redox and electrochemistry, solutions, colloids, carbon compounds, and chemical elements. It is quite common that complaints from high school students show that chemistry is often regarded as a difficult, abstract, unnecessary, uninteresting study, and boring subject [2,3]. This is not only felt by students but also by the teachers who teach chemistry. Content written in textbooks is usually used as a reference by teachers because they often make it a chemistry curriculum. It is not surprising, if students assume that in addition to textbooks, the most important model in teaching chemistry is the chemistry teacher itself.

In reality, student were not the only one who having difficulty to learn chemistry as the teacher is less able to explain the material being taught or the teacher does not provide concrete examples of the reactions that exist in the surrounding environment and often encountered by students. But the least desirable is because there are also teachers who lacking understanding of the material. Studies show that how the teacher constructs the conceptual and how the problem solving process is reflected in the learning outcomes of his students. This also applies to misconceptions that occur in students, especially when abstract concepts are being taught.

Most chemistry teachers in secondary schools also report difficulties and lack of time to teach these subjects. Teachers also realize that the knowledge they have is not enough to know chemical content so they can teach the content well. Therefore, this study aims to identify the understanding of chemical content possessed by chemistry teachers who work in special areas.

2. Methods

This research is a case study research with 30 subjects of chemistry teachers from 14 provinces in Indonesia who are participating in the Special Regional Teacher Education Program in Central Java. Data collection is carried out during the program, starting from September to November 2018.

The technique of collecting data uses a questionnaire that was previously validated by volunteer lecturers. In addition, in-depth interview techniques are also used to gather more detailed information. In the questionnaire, the teachers were asked to describe their impressions about teaching chemistry, showing content they found difficult during teaching in high school, the strategies used, and how students' attitudes were related to the chemical content being taught. In addition, the teachers were also asked to describe their difficulties in developing themselves as professionals, such as the presence or absence of training, the presence or absence of classroom action research programs, discussion of chemistry subject teachers, etc. Furthermore, they were also asked to describe the types of difficulties faced in developing the content and the ways in which he worked to overcome the difficulties. The data obtained were analyzed textually qualitatively, which is based on the presumption of the relationship between what is read / text, in the analysis and the researcher connects the knowledge obtained from the text to the supporting theory.

3. Results and Discussion

When teachers are asked to choose what content is considered difficult to teach to students, it turns out that out of the thirty teachers provide diverse answers, but after being recapitulated almost all content is considered difficult. They report difficulties in all parts of secondary school chemical content, ranging from atomic theory, elemental periodic systems, chemical bonds, organic chemistry.

Chemistry Elements, the nomenclature of inorganic compounds that do not really need mathematical equations, and content that requires mathematical equations such as stoichiometry, solution, thermochemistry, reaction rate and chemical equilibrium. Difficult content delivered by teachers is grouped according to similarity and shown in Table 1.

Table 1. Chemical content that is considered difficult to teach according to the middle school chemistry teacher investigated.

No	Content	Participant Experiencing Difficulties
1	Chemical content that involves mathematical equations	
	Stoichiometry	Molecular concept, chemical calculations 28
	Thermochemistry	Heat reaction, enthalpy of formation, bond energy 21
	Reaction rate	Reaction speed, reaction order 18
	Chemical equilibrium	Set equilibrium, shift equilibrium 20
	Condensation	Properties of acids, bases, salts, calculation of pH, buffer solution, hydrolyzed salt solution, solubility and solubility results, colligative properties of solution 30
	Electrochemistry and electrolysis	Oxidation numbers, redox events, equalization of redox reactions, electrode potential, DGL, electrolysis reactions, Faraday's Law 1 and 2. 19
2	Chemical content that does not involve mathematical equations	
	Colloid	Dispersed phase and dispersing medium, making colloids 17
	The nomenclature of inorganic compounds	Rules for naming inorganic compounds 21
	Carbon Chemistry	Nomenclature of carbon compounds, isomers, types of reactions 17
	Atomic Structure	Electron configuration, orbital diagrams, absorption events and emissions 18
	Periodic System of Elements	Periodic properties of elements which include atomic / ionic radii, ionization energy, electron affinity, electrogativity 22
	Chemical Association	Ionic Bonds, covalent, polarity of bonds, Lewis structure, molecular shape 20
	Chemical Elements	Element Characteristics 17
	Macromolecules, benzene, etc.	Reaction, Name of Compound 16

The content that received many complains of its the level of difficulty is content that in addition to understanding basic concepts also involves mathematical equations. The content included in this category includes stoichiometry, chemical calculations, thermochemistry, reaction rates, chemical equilibrium, solutions, and electrochemistry. In general, teaching this content is a big challenge because besides having to have good mathematical skills (measurement and conversion units, logarithms, etc.) as well as chemical knowledge (symbols, representations, etc.). Examples of "Chemical reaction rates" include many basic concepts of chemistry. Topics in this material include reaction rates, activation energy, factors that affect the rate of reaction, collision theory, catalysts, enthalpies, and reaction mechanisms. These concepts are very important to understand the relationship between chemical and energy change, the type of chemical reaction, and the process of chemical

5
change. It is important for students to understand chemical phenomena in everyday life and explanations from a chemical point of view when they occur. Another example, to learn to understand and balance chemical equations, is the same as learning foreign languages. This is even more difficult, because chemical symbols and grammar are closely related to their conceptual basic principles, and chemical language must be built on an abstract and less well-known knowledge base.

Facts show that more than 90% of program participants find it difficult to understand content that involves mathematical counting skills. This is clearly a matter of great concern. From the interviews, it was revealed that most stated that the main difficulty in teaching this content was "low mathematical foundation" or "low in the ability to interpret statements or questions." Teachers in teaching only choose questions with simple calculations. If they are given questions related to roots, logarithms, quadratic equations, differentials, and integrals, they will experience difficulties.

The teachers stated that the content of chemical equilibrium and thermochemistry are also difficult to teach and to learn, perhaps because they are abstract. Several studies have proven this. [4] convey students' difficulties in the concept of chemical equilibrium related to the level of abstraction and the fact that the concepts involved have different meanings than those in everyday life. Many teachers are not right when using Le Chatelier's principles. In thermochemical materials, to avoid miscalculation, keep in mind the convention: negative signs apply when the system loses energy, and a positive sign when the system gains energy. In the process that takes place in an open system, the pressure is considered constant.

The teachers also conveyed, electrochemistry is categorized as one of the toughest topics in chemistry for middle school students. Students are usually difficult to master this topic, because it requires high-level thinking skills that involve microscopic, macroscopic and symbolic levels of representation [5]. Electrochemistry is also said to be abstract for students. The movement of electrons is not visible and some students may not be able to visualize the movement of electrons. Students need to understand the movement of ions and electrons during the electrolysis process, and only then can they change the process into chemical formulas and equations [6].

Emphasis on mathematics from content will contribute to the development of thinking skills in chemistry. Fortunately, the complexity of quantum models for chemical bonds, the concept of atomic orbitals (AO), molecular orbitals (MO), hybridization theory, valence bond theory which is also produced based on mathematical calculations are not studied by middle school students.

Content that is also in dire need of basic chemical knowledge, for example in carbon compounds, which are classified as organic chemistry. Carbon hybridization, atomic orbitals and molecular orbitals, reactions of organic compounds, and reaction mechanisms are part of this category. According to the teachers there are certain materials that are forced to be "ignored" because it is impossible to explain to students with a short number of meetings. Examples such as "reaction mechanism". How much middle school students learn about it? when teaching the content, the teachers realized that it was abstraction. With limited time, the method chosen is memorization. Because the structure of the atoms and molecules involved in the reaction cannot be felt by the senses even though they are real, this is where the teacher's difficulties arise.

Another teacher mentioned the difficulty of teaching electron distribution and energy sublevels because they lacked understanding of the Bohr model. The Bohr atomic model successfully explains atomic stability, ionization energy, and the hydrogen-like ion spectrum (Balmer series), that is, atoms that have a single electron (for example, He^+ , Li^{2+} , and Be^{3+}). The teachers also avoid formulation of questions that involve energy sublevels because they feel this content belongs to higher education, because it is too deep. From the comments of several teachers, we can conclude even though they continue to teach this content and describe it, but they still call it difficult content, because there is no challenge to learn more.

The periodic nature of the elements is also mentioned by the teachers as difficult content. The teacher does not experience difficulties when explaining how to determine the class and period of an element in the periodic system of elements. But the teachers stated the difficulty of having to answer questions about atomic radius, ionization energy, electron affinity, acid base strength, and solubility in

1
water. Regarding students' interest in this content, one teacher said that they liked the periodic nature of the elements because they understood their electron configuration.

The same results were also experienced by teachers in Thailand and Kenya. As per the syllabus in the two countries, the Atomic structure and the periodic system of elements are the initial topics learned. Teachers in both countries stated that concepts in atomic structure and periodic tables are difficult to teach because this is an abstract topic and students have to imagine a lot to build understanding of things that cannot be seen. Teachers do not seem to have sufficient knowledge to build their own teaching models for use in teaching. For Thai high school chemistry teachers, all concepts of atomic structure including atomic models, subatomic particles and electron configurations are considered difficult to very difficult (18/24 = 75%), as well as the periodic table (17/24 = 71%). For effective understanding of the periodic table by students, the teacher must discuss valence first, followed by the chemical formula of the compound, and then the chemical equation. If the teacher has a low understanding of the concept of valence, then the preparation of the chemical formula will experience difficulties, as well as for the equation of the reaction[7].

Chemical concepts that involve bonds between atoms and / or molecules are quite abstract and far from everyday experience. These difficulties are a source of important misconceptions that must be minimized, given the importance of the concept of chemical bonds to successfully learn more about other chemical concepts such as chemical reactions, structural substances, organic compounds, proteins, polymers, etc. The results showed that students could not distinguish ionic and covalent bonds [8,9], students did not understand the electrostatic properties of chemical bonds [10], and experiencing misconceptions about molecular polarity and molecular geometry [11]. This difficulty may be because the teacher is also still experiencing difficulties in teaching his students.

The results of the study found that students were confused between intra and inter-molecular styles [9] As already stated that students' abilities are a reflection of the teacher's ability to teach. If students are confused, chances are the teacher has experienced a misconception. The concept of intra-style and between molecules, one of which will result in the magnitude of the boiling point and melting point of the compound. The teacher must understand that different substances have different melting and boiling points, they need to consider the magnitude of the interatomic and intermolecular forces of the substance and the intensity of both. These concepts also require to be able to classify substances correctly according to the type of bond (ionic, covalent, molecular or metal), and in special cases of molecules, the teacher must also take into account the possibility of hydrogen bonding. Do not let students experience misconceptions about melting and boiling points or on solubility and conductivity of substances [12].

However, they seem to have difficulty in preparing it in class, because of its various limitations. What we get from the findings in this study in relation to teacher difficulties related to understanding chemical content allows us to describe the profile of students in secondary education in special areas.

4. Conclusion

Based on the results of the study, it is shown that the level of understanding of the chemical concepts of teachers in special areas was relatively low. This can be seen from the results of identification of concepts that are considered difficult by the teacher, evenly distributed in all concepts taught in high school / vocational school. We have not observed greater difficulties in understanding stoichiometry, chemical calculations, or other content. It could be the source of difficulties in chemical equations, derived from the inability to understand chemical transformation. Why is this assumption? Because to think about the quantity in chemical equations depends on understanding the chemical transformations involved. In studying chemistry, we cannot be limited to memorizing or using formulas and words that have no meaning, but how the concept was originally presented.

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