Analysis of chemical concepts as the basic of virtual laboratory development and process science skills in solubility and solubility product subject

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Abstract. This study aims to analyze the concept characteristics of solubility and solubility products that will serve as the basis for the development of virtual laboratory and students' science process skills. Characteristics of the analyzed concepts include concept definitions, concept attributes, and types of concepts. The concept analysis method uses concept analysis according to Herron. The results of the concept analysis show that there are twelve chemical concepts that become the prerequisite concept before studying the solubility and solubility and five core concepts that students must understand in the solubility and Solubility product. As many as 58.3% of the definitions of the concepts contained in high school textbooks support students' science process skills, the rest of the definition of the concept is memorized. Concept attributes that meet three levels of chemical representation and can be poured into a virtual laboratory have a percentage of 66.6%. Type of concept, 83.3% is a concept based on principle; and 16.6% concepts that state the process. Meanwhile, the science process skills that can be developed based on concept analysis are the ability to observe, calculate, measure, predict, interpret, hypothesize, apply, classify, and inference.

1. Introduction
Chemical learning as a part of natural science cannot be separated from practicum activities. Practicum is a way of presenting a lesson in which students experiment with experiencing and proving themselves something studied [1]. Practicum provides students the opportunity to prove the concept that has been obtained previously. In line with that, the practicum method can also help students develop the skills of the science process. Scientific process skills are an activity, in which students undertake scientific inquiry to enable the acquisition of scientific knowledge and skills. The skill of the process of science cannot be separated in practice from the conceptual understanding involved in learning and applying science [2]. The importance of teaching science process skills is to enable students to describe objects and events, ask questions, build explanations, tempt them explanations of current scientific knowledge and communicate their ideas to others [3]. The existence of scientific process skills in chemistry learning can help students understand concepts, adopt attitudes, and improve skills related to chemistry classes [4]. Integrated science process skills involve students in identifying and controlling variables, defining operationally, formulating hypotheses, experimenting including being able to design their own experiments to test hypotheses using procedures to obtain reliable data, interpret data and draw conclusions, and formulate mental models or physical a process or event [5]. If students actively engage
in Science processes they can come to recognize that scientific knowledge is based on experiments in which meaning of data is negotiated and theories are not absolute [6]. While science process skills as a means for understanding and mastering science can be assessed, they are also a major goal of science education, since those skills are not only needed by scientists, but by every citizen in order to become a scientifically literate person able to function in a society where science has a major role and impact on everyone’s personal, social and global life [7,8] Through his research findings concluded that the use of effective practicum methods on students’ science process skills.

One of the chemicals that can be studied through the practice method is the subject of solubility and solubility product. Solubility and solubility products are categorized as the most difficult material for students to understand because of the scope and breadth of the material. When understanding the material, students must connect many other chemical concepts such as the concept of molarity, chemical equations, the nature of matter, ionic compounds, chemical equilibrium, and Le Chatelier principle [9,10]. Students generally have difficulty in understanding the solubility material and solubility results because the learning material involves an understanding of the macroscopic, submicroscopic, and symbolic levels [11]. Implementation of the lab in learning chemistry has various obstacles such as not being able to provide explanation until submicroscopic level. In addition there are several reasons teachers avoid practicum, including the existence of doubt on security in the experiment, lack of confidence to conduct experiments, as well as insufficient time [12]. In practice, the lab requires a high budget, a long time, difficulty checking student performance during the lab, as well as limited laboratory conditions [13]. In this case the technology can be a solution to overcome the limitations of practicum implementation. By utilizing technology can be created a practical method that can visualize concretely phenomena that occur in solubility practice and solubility product that is by using virtual laboratory.

There are many applications and advantages of virtual laboratories as their implementation in distance education or the acquisition and management of expensive tools and machinery that is not easily acquired. The virtual lab allows learning activities that are free from time and place. Students show active participation while experimenting virtually, they can experiment individually or in groups. Virtual laboratory that provides students with opportunities such as enriching their learning experience; conducting experiments as if they were in a real laboratory; and improved their experiment related skills as it manipulates materials and equipment, collects data, completes experimental processes in an interactive way (with unlimited inventory), and prepares experiment reports [14]. The first step in designing a virtual laboratory on solubility and solubility is to do a concept analysis. Conceptual analysis is a formal procedure for examining and determining how students can be taught [15]. In this research, concept analysis is done to know the concept of prerequisite and core concept on solubility and solubility product which must be mastered by the students. In addition, concept analysis is conducted to find out the concept attributes and concept types that meet the criteria of the three levels of chemical representation that can be visualized into a virtual laboratory.

Based on the description, this study aims to analyze the characteristics of the concept as a basis for the development of virtual laboratory that can build students’ science process skills on solubility and solubility.

2. Methods
The research method to analyze the chemical concepts used in this study is concept analysis according to Herron [15]. Herron identifies characteristics that a concept possesses: concept labels, concept attributes (critical attributes and variable attributes), and types of concepts. The sample in this study consisted of two textbooks of chemistry curriculum SMA Curriculum 2013 used in schools.

3. Results and Discussion
In chemistry of solubility and solubility product, students must have some prerequisite concepts that form the basis for establishing core concepts on solubility and solubility product. Based on the results of concept analysis conducted, there are several concept labels that become the prerequisite concept that must be mastered before the students go to the core concept of solubility and solubility product. The
concept of the prerequisite is the equilibrium and dynamic equilibrium constant. While the core concept labels of solubility and solubility are the solubility, the product of solubility, and the influence of the ion on the solubility.

A label concept can have different concept definitions. This is of course adjusted to the level of achievement of the expected concept of the students. In the development of virtual laboratory concept definition leads to the definition of concepts that can develop students' science process skills. Therefore, the definition of the expected concept is not memorized, but rather the explanations that are able to lure students to perform the analysis before finding the definition of the actual concept. From the results of concept analysis, high school chemistry textbook 58.3% concept definition has led to the development of students' science process skills. Although not all concepts refer to the development of students' science process skills, the concept definitions contained in most high school books can be an early step in the development of virtual laboratory on solubility and solubility. Here are some analysis of the definition of the concept of a high school chemistry book:

3.1. Predefined concept labels
To label the concept of prerequisites presented the results of the concept analysis of equilibrium constants and dynamic equilibrium.

3.1.1. Concept label of the equilibrium constant
Concept Definition: (1) "The result for the concentration of the product is generated by the reaction coefficient and the reactant is raised. The reaction coefficient always gives the same value at a certain temperature, called the equilibrium constant (K_c)"  (2) “K_c is a constant or constant of concentration equilibrium whose price remains as long as the temperature remains". Analysis concept : The concept definition used in high school chemistry textbooks will only make students memorize, and this is certainly not enough to help students develop their science process skills.

3.1.2. Concept label of dynamic equilibrium Label
Concept Definition: (1) "In the evaporation and condensation reaction of water occurring in closed bottles, a dynamic equilibrium state is achieved when the reaction is continuous at the same rate in both directions. So dynamic equilibrium can only occur in an alternating reaction in a closed system. " (2) "The circumstances in which the reaction takes place continuously and the speed of forming a product substance equal to the speed of decomposing a reactant is called dynamic equilibrium.
Analysis concept: The type of concept in this definition is the concept that states the process (evaporation & water condensation). Definition comes with a phenomenon that can help students to develop science process skills, such as observing skills.

3.2. Important Concept Labels
The important concept labels are presented on the results of solubility concept analysis and the effect of ion names on solubility.

3.2.1. Solubility
Concept Definition: (1) "The solubility (s) of the solute is the maximum amount of solute that will dissolve in a certain amount of solvent. Solubility solubility in a particular solvent depends on the temperature" (2) "The solubility term is used to express the maximum amount of solute in a certain amount of solvent". Analysis concept: In the first definition looks kind of concept that is the concept based on principle, where in principle the solubility of each substance in a particular solvent and a certain temperature vary. Although the concept attributes are already visible, the concept-definition writing style is still rote so it is less helpful for students to develop their science process skills. While in the definition of the concept of the second attribute concept is not yet complete, which does not include the temperature variable in the definition of the concept. In addition, the writing of concept definition is still memorized.
3.2.2. The effect of similar ions on solubility

Concept Definition: (1) "What would happen if the saturated solution of calcium oxalate was added a solution of calcium chloride (CaCl$_2$) saturated solution of CaC$_2$O$_4$ to equilibrium as follows:

$$CaC_2O_4(s) \rightleftharpoons Ca^{2+}(aq) + C_2O_4^{2-}(aq).$$

Calcium chloride (CaCl$_2$) is a water-soluble salt and decomposes into Ca$^{2+}$ ions and Cl$^{-}$ ions according to the following reaction:

$$CaCl_2(aq) \rightleftharpoons Ca^{2+}(aq) + 2Cl^-(aq).$$

CaCl$_2$ solution has an ion of name with CaC$_2$O$_4$, Ca$^{2+}$ ion. If the CaCl$_2$ solution is added to the CaC$_2$O$_4$ solution, there will be an increase in the concentration of Ca$^{2+}$ ions in the solution. In accordance with the Le Chatelier principle, the addition of Ca$^{2+}$ ion concentration will shift the equilibrium to the left thus reducing the amount of soluble CaC$_2$O$_4$. Thus, it can be concluded that the namesake ion will decrease salt solubility.

(2) "What happens when the saturated solution is added AgNO$_3$ or K$_2$CrO$_4$ solution? The addition of AgNO$_3$ or K$_2$CrO$_4$ solution will increase the concentration of Ag$^+$ or CrO$_4^{2-}$ ions in solution. According to Le Chatelier's principle of equilibrium shift, adding the concentration of Ag$^+$ ions or CrO$_4^{2-}$ ions will shift the equilibrium to the left. As a result the amount of soluble Ag$_2$CrO$_4$ becomes reduced. So it can be concluded that similar ions minimize solubility.

Analysis concept:
The two definition definitions are not memorized so as to help students develop their science process skills. With a question at the beginning of the sentence, the student will analyze the next explanation, and this process is very helpful for students to develop their science process skills before finally getting to the definition of the real concept.

Based on the results of concept analysis, the next step is to determine the suitable process skills to be developed using virtual laboratory. There are ten indicators of science process skills: 1) observation, 2) calculation, 3) measurement, 4) classification, 5) spatial/time relationship, 6) hypothesis making, 7) research/experimental planning, 8) variable control, 9) interpret, 10) inference, 11) forecasting, 12) application, 13) communication. Some of the science process skills that can be developed according to the prerequisite concept labels and core concepts are presented in the following table.

Table 1. Scientific process skills that can be developed in accordance with the prerequisite concept labels and core concepts.

| No | Concept Label       | Concept Definition                                                                 | KPS concept developed                      |
|----|--------------------|-----------------------------------------------------------------------------------|---------------------------------------------|
| 1  | Equilibrium constant | The equilibrium constant represents the measure of the occurrence of dynamic equilibrium. The value of K is calculated from the multiplication of the concentrations of the product substances in which the coefficients are respectively divided by the concentrations of the reactant substances with the coefficients. | Ability to calculate and application        |
| 2  | Dynamic equilibrium | In dynamic equilibrium, there is a process of continuous change towards the reaction of product formation and reactant re-formation simultaneously so that the concentration of the product and the reactant does not change. | Ability to reference, predict, making hypothesis |
| 3  | Solubility          | The dissolution of a substance until it reaches the maximum amount (forming a saturated solution) in a solvent and a certain temperature is referred to as solubility. NaCl and CaCO$_3$ of the same amount when put into water, then NaCl will dissolve all while CaCO$_3$ can not dissolve | Ability to observe, interpret.             |
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| No | Concept Label | Concept Definition | KPS concept developed |
|----|---------------|-------------------|-----------------------|
| 4  | Solubility Constant Product | The size of the occurrence of equilibrium between insoluble solids and their ions is expressed in $K_{sp}$. $K_{sp}$ can be calculated by multiplying the cation and anion concentrations of the soluble compounds of the coefficients of each ion of the stoichiometric equation. | Ability to observe and interpret. |
| 5  | Solubility process | The presence or absence of the insoluble substances in a given solution can be determined by calculating the ratio of the $Q$ value to the $K_{sp}$ value ($K_{sp}$ value data of soluble ionic compounds based on the experiments already performed). 
- If $Q_{sp} < K_{sp}$, Unsaturated solution (no residual solute)
- If $Q_{sp} = K_{sp}$, The solution is saturated precisely (dissolved substances not yet left)
- If $Q_{sp} > K_{sp}$, There are residual solutes that do not dissolve in the solvent. | Ability to predict, communicate. |
| 6  | The effect of similar ions on solubility | When a solute has an ion similar to a solvent / solvent then between the solute and the solvent will have one of the same ions / similar ions. The namesake ions will affect the solubility of a solute. With the existence of ion names in the solution it will disrupt the reaction of equilibrium solubility. According to the principle of Le Chatelier, the existence of the namesake ion will shift the equilibrium to the left so that the solubility of solids will decrease. In principle, the influence of the namesake ion is based on the principle of equilibrium according to the Le Chatelier principle. | Ability to predict, communicate, interpret classify. |

The next concept analysis is the concept attribute. The concept attribute is divided to critical attributes and variable attributes [8]. Critical attributes are the elaboration of concept definitions which are also the main features of the concept definition. While the variable attribute is a characteristic of the concept whose value may change, but the amount and unit remain. Concept attributes that meet three levels of chemical representation and can be poured into a virtual laboratory have a percentage of 66.6%. The results of the analysis are presented in the following table.
### Table 2. Concept attributes that meet three levels of chemical representation and can be poured into a virtual laboratory.

| No | Concept Label                  | Critical Attribute                                                                 | Variable Attribute                        | Aspects of Visualization |
|----|--------------------------------|------------------------------------------------------------------------------------|------------------------------------------|--------------------------|
| 1  | Equilibrium constant           | - Equilibrium constant                                                             | - Equilibrium                            | - Simbolic               |
|    |                                | - The size of the occurrence of dynamic equilibrium                                | - Product concentration                 |                          |
|    |                                | - Concentration of product raised coefficient                                      | - Reactant concentration                 |                          |
|    |                                | - Reactant concentration is raised coefficient                                      | - Temperature                            |                          |
| 2  | Dynamic equilibrium            | - Dynamic equilibrium                                                              | - Concentration of product               | - Submikroscopic         |
|    |                                | - The process of continuous change towards product formation                       | - Reactant concentration                 | - Makroscopic            |
|    |                                | - Re-formation of reactants                                                        |                                        | - Simbolic               |
|    |                                | - The concentrations of products and reactants remain.                              |                                        |                          |
| 3  | Solubility                     | - Solubility                                                                        | - Type of solute                         | - Submikroscopic         |
|    |                                | - The event of the dissolution of a substance                                       | - Maximum amount of solute               | - Makroscopic            |
|    |                                | - Maximum number (form saturated solution)                                         |                                        | - Simbolic               |
|    |                                | - Specific solvents and temperatures.                                              |                                        |                          |
| 4  | Solubility Constant Product    | - Solubility and solubility product \( (K_{sp}) \)                                  | - Saturated solution                     | - Simbolic               |
|    |                                | - The size of the equilibrium                                                      | - Temperature                           |                          |
|    |                                | - Solid substances do not dissolve with their ions                                   |                                        |                          |
|    |                                | - The product of cation and anion concentration                                     |                                        |                          |
|    |                                | - Coefficient lifted                                                                |                                        |                          |
|    |                                | - Saturated solution                                                                |                                        |                          |
|    |                                | - Stoichiometric equation                                                           |                                        |                          |
The final concept analysis is to determine the type of concept from prerequisite concept labels and core concept labels. According to Herron, there are eight types of concepts: 1) concrete concepts, 2) abstract concepts, 3) abstract concepts with concrete examples, 4) concepts based on principles, 5) concepts expressing symbols, 6) concepts that state the name of process, 7) Concepts that state the properties and attribute names, and 8) concepts that state the size of the attribute. Based on the results of label analysis of prerequisite concepts and core concept labels, obtained the following results 83.3% concept label is a concept based on principle; and 16.6% concepts that state the process. The results of concept type analysis are presented in the following table.

**Table 3. Concept Types Analysis Result**

| No | Concept Label | Concrete | Abstract | Abstract with concrete example | Type of concept | Symbol | Process | Properties and attribute names | Attribute size |
|----|---------------|----------|----------|--------------------------------|----------------|--------|---------|-------------------------------|----------------|
| 1  | Equilibrium constant | -        | -        | -                              | √              | -      | -       | -                             | -              |
| 2  | Dynamic equilibrium | -        | -        | -                              | -              | -      | -       | √                             | -              |
| 3  | Solubility    | -        | -        | -                              | √              | -      | -       | -                             | -              |
| 4  | Solubility Constant Product | -        | -        | -                              | √              | -      | -       | -                             | -              |
| 5  | Solubility process | -        | -        | -                              | √              | -      | -       | -                             | -              |
| 6  | The effect of similar ions on solubility | -        | -        | -                              | √              | -      | -       | -                             | -              |

**Percentage** 83.3% 16.6%
4. Conclusion
Based on the results of the concept analysis, the definition of concepts contained in high school textbooks related to solubility and solubility results in both prerequisite and core concepts can be used as a starting point for designing virtual laboratory that can build students’ science process skills. However, there are still some rhetorical definition definitions that do not help students to build their science process skills. In addition, based on the analysis of the concept is illustrated some indicators that can be raised in the virtual laboratory include the skills to observe, calculate, measure, predict, interpret, hypothesis, apply, classify, and inference.

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