Prospective chemistry teachers’ perceptions of multiple representation and ability to represent voltaic cell subject

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Abstract. The aim of this research was to obtain information about students’ perceptions concerning the importance of multiple representations including macroscopic, sub microscopic and symbolic level in chemistry teaching materials, the difficulties in learning voltaic cell, and the ability to present voltaic cell material through those three level of representations. Participants of this study were twenty one students of chemistry education program at the fifth semester, who are taking the subject of school chemistry in the one of the university in Indonesia. The instruments used were questionnaires and interview. They are utilized to gather the students’ perceptions about the characteristics of voltaic cell material, the students’ knowledge of multiple representations and those representations in chemistry teaching materials, and the rubric assessments of teaching materials based on those representations. This study indicates that the students consider the voltaic cell subject as difficult material. Even though they do not understand the multiple representations, they encourage to involve those representations in the teaching materials. Furthermore, the students’ ability of presenting the multiple representations are considered in the low category. They are not be able to apply those representations and associate one and another.

1. Introduction

Teaching materials or textbooks are used as communication tool to share knowledge [1] which if used properly will be an effective tool to improve teaching and learning process [2]. As one of the source learning, teaching materials play a major role in the learning process. In the context of chemistry teaching materials, they should contain of the phenomena of the materials being studied and these phenomena are basically related to three types of chemistry representations, called as multiple representations, involving macroscopic, submicroscopic and symbolic level. Those representations are inseparable from textbooks which play a significant role to understand various chemistry concepts and act as an teaching aids [3] because both teachers and students utilize them as their main guidelines [4] and used as primary tool to obtain knowledge [5]. Therefore, the multiple representations are important in developing teaching materials [6] and all three levels of representation must be included in teaching materials [3]. Representations becomes a standard in chemistry education because it is able to explain critical thinking and learning through all three levels [7].

The use of multiple representations is effective to improve learning process [8]. The use of multiple representation also facilitates the students to understand the concepts in depth [9-17]. In the teaching materials, it can develop the students’ ability to present the concepts [18].
Voltaic cell is one of the chemistry material. It is required the ability to integrate all representation in order to understand this subject [18]. Voltaic cell material is categorized as the abstract concepts which provide concrete examples [19]. Furthermore, it is considered as difficult [20-23] because it is related to electricity currents and redox reactions [23] and involving macroscopic, submicroscopic and symbolic level [24]. The complexity is not only caused by the learning process, but also the textbooks [25]. In relation to the textbooks, it is usually associated to representation they employ. In the level of senior high schools, the study shows that their textbooks do not even present the submicroscopic level and the relationship of all representation [26], the macroscopic level is not associated with submicroscopic level, and the image visualization does not show proper chemical relations [25, 27].

As the chemistry prospective teacher, the students should possess an understanding of multiple representations in learning and teaching materials. However, the literatures regarding the students’ perception concerning these representations are still limited. Hence, this study aims to obtain information about prospective chemistry teachers’ perceptions of multiple representations in teaching materials, the difficulties encountered in studying voltaic cell, and the prospective chemistry teachers’ ability to present the emergence of electricity in voltaic cell material. This research was conducted as a first step to find out prospective chemistry teachers’ perceptions of multiple representation and ability to represent voltaic cell subject, so that it can be used as abasis for providing concept representation in writing teaching materials.

2. Methods
This study used a case study approach involving twenty-one students of chemistry education program at the fifth semester, who are taking the subject of school chemistry in the one of the university in Indonesia. The participants consisted of 4 men and 18 women aged between 20 and 21 years. They have completed a general chemistry course, a general chemistry practicum, a physical chemistry course and a physical chemistry practicum.

There were some instruments conducted in this study. First, questionnaire and interview were employed to gather the students’ perceptions of multiple representations in the chemistry subject and the difficulties encountered in learning voltaic cells. The second was the rubric assessment of multiple representation in the teaching materials of voltaic cell produced by the students. These instruments have been validated through making judgements to the experts.

The analysis data of questionnaires and interviews was conducted by calculating the number of answers ‘yes’ and ‘no’, ‘correct’ and ‘incorrect’, then changing the results in percentage form. Meanwhile, the assessment of teaching materials was conducted by determining the appearance of each macroscopic, submicroscopic and symbolic level and the relationship between macroscopic level and symbolic level. Furthermore, the data were analyzed through the editing, concentrating and hypothesizing process. The results were guaranteed by triangulation process.

3. Results and Discussion

3.1. Students’ knowledge concerning multiple representation.
Figure 1 shows that the results data in measuring oil viscosity. Please put the results of your research in the form of narration completed with figure or picture when it is needed. Add discussion to your research results accomplished with referring to adequate relevant source. The results of students’ knowledge concerning multiple representations which are obtained through questionnaire are shown in Table 1.
Table 1. Students’ Knowledge Concerning Multiple Representations

| No | Questions                        | Correct | Nearly correct | Incorrect / No Answer |
|----|----------------------------------|---------|---------------|----------------------|
| 1  | Describing multiple representation | 0       | 14.29%        | 85.71%               |
| 2  | Mention the level representations | 14.29%  | 38.09%        | 47.62%               |
| 3  | Describing macroscopic level      | 0       | 4.76%         | 95.24%               |
| 4  | Describing submicroscopic level   | 0       | 9.52%         | 90.48%               |
| 5  | Describing symbolic level         | 0       | 85.71%        | 14.29%               |

Table 1 indicates that most students (85.71% or 18 people) do not know about multiple representations and their levels. The following examples are the nearly correct answers created by the students regarding what multiple representations are.

**Answer 1:** "Multiple representation is a way of representing a concept using several types of representation"

**Answer 2:** "Multiple representation is a method used to understand the material being studied"

The students’ knowledge of chemical level representations or multiple representation is at the low level. Only a few students (14.29% or 3 people) can mention all level of representations completely. A total number of students which can mention some level of representations is 38.09% or 8 students. Meanwhile, there are 47.62% or 10 people which cannot mention all level representations.

According to the data obtained through questionnaire, it is revealed that no students can describe each level of representation correctly. Less than 10% students provide nearly correct answers regarding the macroscopic level and submicroscopic level. Furthermore, 85.71% students provide nearly correct answers regarding symbolic level. The following examples are the answers created by the students regarding the three levels of representation.

**Answer 1:** "Macroscopic level is something that can be seen as macro"

**Answer 2:** "The submicroscopic level is an invisible detail explanation"

**Answer 3:** "The symbolic level is a symbol or symbol"

According to the data gained through interviews conducted to the 5 participants, it can be inferred that they have never studied multiple representations specifically. They briefly know the term ‘multiple representations’ when studying in previous semesters. They cannot explain the relationship of each level of representation as well. As a result, this result strengthens the questionnaire results which reveal that most students cannot provide a precise explanation of multiple representations and all levels of representation.

In line with the result of both instruments, it is found that the students do not have sufficient knowledge about multiple representations. The new students are limited to recognize that there are several types of representations used in multiple representations. Generally, they are not able to correctly mention and explain all levels of representation and to identify the relationship between each level of representation. It is in line with the statement stating that multiple representations employ various modes of representation to link the three levels of chemical representation [28].

3.2. Students’ perception of voltaic cell material and difficulties faced when learning it

Based on the questionnaire given, it is found that most of students (66.7% or 4 people) categorize voltaic cell as difficult material. The complexity is revealed through the result of interviews. The students tend to view that there are similarities between voltaic cell and electrolysis cell. The students face the difficulty in determining a negative and positive sign on the electrode, determining the reaction that occurs at the electrode and the direction of the electron flow. On the other side, a small number of other students (33.3% or 7 people) consider voltaic cell material as the material which is not difficult to learn because the macroscopic material can be easily demonstrated through practical or experimental activities.

Students categorize voltaic cell material as an abstract concept (23.8% or 5 people) because the process or reaction occurs in the voltaic cells cannot be observed directly. Most students stress that
voltaic cell is a concrete concept (76.2% or 16 people) because it is merely demonstrated in the daily life even though the reaction occurrence in the voltaic cells cannot be observed directly. This perspective is a contradiction with Heron’s study where voltaic cell is considered as an abstract concept which provide concrete examples [19]. The students consider voltaic cell material as a concrete concept. They can see the example of voltaic cell and do not pay attention to the working principle of voltaic cell which is an abstract concept. The abstract concept means that we cannot observe what happens in the reaction, such as an oxidation reaction that releases electrons, a reduction reaction involving electrons and electron flow that occurs when the reaction takes place.

3.3. Ability of Presenting Multi Level Representation

The data concerning the students’ perception of multiple representations are obtained through writing description about voltaic cell. The results can be seen in Table 2.

| No | Indicator                                               | Total     |
|----|---------------------------------------------------------|-----------|
| 1  | Applying macroscopic level                            | 80.95%    |
| 2  | Applying submacroscopic level                         | 61.91%    |
| 3  | Applying symbolic level                               | 100%      |
| 4  | Linking macroscopic to submacroscopic level           | 9.52%     |
| 5  | Linking macroscopic to symbolic level                 | 0%        |
| 6  | Linking macroscopic to submacroscopic to symbolic level | 0%        |

Table 2 show that a high number of students (80.92% or 17 people) bring up the macroscopic level of voltaic cells in their teaching material which can be seen from the following examples.

Statment 1: "Voltaic cells are cells that produce electricity"
Statment 2: "Voltaic cells are cells that produce electricity by utilizing spontaneous redox reactions"
Statment 3: "Voltaic cells are chemical series that produce electricity currents from chemical changes where spontaneous redox reactions occur"

As seen from the students’ statements above, they cannot conduct correctly the voltaic cells on the macroscopic level. They intend to show voltaic cells which can produce electrical energy, however, they do not reveal how electricity energy can be observed. Therefore, it can be inferred that the students are not be able to present voltaic cells at the macroscopic level appropriately. They are phenomena which can be observed directly or by tool assistance [6, 29, 30]

On the other hand, most students (80.9% or 17 people) prove their perception through the teaching materials they create. They extremely encourage to apply macroscopic levels in teaching materials and, although it is not fully correct, they demonstrate it in their writing. The following examples are the material of the submicroscopic level which appears in the teaching materials.

Statment 1: "In the voltaic cells, they occurs an electron flow in the wire during the reduction oxidation reaction"
Statment 2: "In the voltaic cells, there are electron transfer through the outer path"
Statment 3: "Electrons flow from the anode during oxidation to the cathode"

Only a few student (14.29% or 3 people) wrote those statements. According these result, it can be inferred that the students want to demonstrate the voltaic cell process. The process includes the submicroscopic level which provides an explanation at the particulate level through a picture of the arrangement of atoms, molecules, ions, or electrons [29, 30].

Most students (47.62% or 10 people) wrote "a redox reaction occurs in the anode and cathode caused by a potential difference in voltaic cells". This statement express the students would like to demonstrate a reaction process in voltaic cells.

Based on the results above, it can be inferred that there is an equivalence of the students’ perception and their teaching materials they made. The students manage the submicroscopic level in their teaching materials, even though they are not still appropriate due to their inadequate knowledge of multiple
representations. The representation of the symbolic level that appears in the teaching materials can be seen in Figure 1.

**Figure 1.** Symbolic representation of voltaic cells made by students

All students explain the form of a voltaic cell series and the reaction process as in Figure 1. In line with the symbolic levels involving the use of symbols, formulas and diagrams, this figure is appropriate as a symbolic level for voltaic cells [29-30]. The figure demonstrates symbols through a reaction equation, a graph or picture of voltaic cell series, and a picture showing the movement of atoms and electrons. Based on the figure, it can also be inferred that there is a relationship between students' perceptions of multiplerrepresentations and their teaching materials they create. They view that teaching materials must contain a symbolic level, thus they write it on their teaching materials as shown in Figure 1.

The relationship between each representation can be seen from the writings made by students. Only a few student (9.52% or 2 people) can associate the representation of macroscopic levels with representations of submicroscopic levels.

They can link between the statement "voltaic cells are cells that can produce electrical energy" and "electricity comes from the flow of electrons produced from spontaneous redox reactions flowing through the outer path of wire connected to a volt meter, so that the volt meter moves or appears the numbers". Some other students cannot associate where the electricity is generated in voltaic cells. They generally mention that "there is a spontaneous redox reaction at the cathode and anode in voltaic cells since there is the potential of the differences".

The students are not be able to associate between macroscopic and symbolic levels in their teaching materials. It can be seen from them which state "voltaic cells are cells that can produce electrical energy", but the images they show are as in Figure 1. The students demonstrate this figure to explain voltaic cell lines and reactions that occur in voltaic cells, not to show how voltaic cells can produce electricity. The students are not be able to associate the three levels of representation in their teaching materials. They generally can not connect macroscopic with symbolic representations.

4. Conclusion

Based on the results of study, it can be inferred that the students consider voltaic cell material as difficult material to learn due to the similarity between voltaic cells and electrolytic cells. Then, the students misinterpret voltaic cells as a concrete concept which should be regarded as abstract concepts with concrete examples. The students’ knowledge of multiple representations including all levels are considered at a low level. The students view that the multiple representations need to be present in chemistry teaching materials to facilitate learning process. The students’ ability of multiple representations in voltaic cell are still inadequate. The students cannot produce each level of representation appropriately and are not been able to associate one and another correctly.
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