

## Students' Skills to Make Inductions and Consider Inductions to Explain the Phenomenon of the Volta Cell

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### ABSTRACT

Make induction and consider induction descriptor is one of important critical thinking skills for students in order to succeed facing dynamic and complex world. The purpose of this study was to improve the students' make induction and consider induction skills (MICIS) through voltaic cell laboratory activities based on their mental models. It was also to know the excellence dan the limitations of this learning. It was a *weak experimental design with one group pretest posttest design*. The study involved 12 students who took General Chemistry II, one of university in Papua. The instruments were essay test, observation sheet, students' worksheet, and questioners. Essay test of 2 items was used to analyze their MICIS that calculated by N-Gains value. Each items was designed to interconnect macroscopic, sub-microscopic, and symbolic levels. Students' MICIS (was increased through this learning (N-gain=63,75%). It is necessary to interconnect the three level of chemistry representation level for increasing the students' MICIS in studying chemistry.

## **INTRODUCTION**

Workers who have the skills to think critically, think creatively, make decisions and solve problems are needed to face global competition in the 21st century (Liliasari, 2005). Basic Chemistry is one of the subjects that must be studied by prospective chemistry teachers which includes Basic Chemistry Practicum. One of the topics studied in Basic Chemistry II is redox reactions that produce electricity (Volta cells). Critical thinking skills (KBK) are one type of thinking skills that need to be provided and improved to prospective chemistry teacher students. Critical thinking skills are useful for yourself and others to make wise decisions in everyday life.

On the other hand, students need to link macroscopic phenomena with submicroscopic and symbolic explanations in studying chemistry material in order to have a complete understanding of chemistry. Students' ability to understand and describe the three levels of chemical representation reflects the mental model they have (Chittleborough, 2004). A mental model is an internal cognitive representation constructed by a person, including a visual-pictorial component and a propositional component to understand or provide a rational explanation of a real world phenomenon or imaginary situation, event or process whose structure reflects a perceived structure of the situation, event or process (Wang & Barrow, 2010; Tumay, 2014).

So far the Basic Chemistry II lectures on voltaic cell material held in the chemistry education study program at one of the universities in Papua have focused more on explanations at the symbolic level of observed phenomena. The implementation of Basic Chemistry II Practicum so far tends to be verification in nature, students carry out practicum based on procedures created by the lecturer (cook book).

Electrochemistry is one of the topics studied by prospective chemistry teachers in Basic Chemistry II lectures. Miler (2014) explains that there is a tendency for students to experience misconceptions and errors when studying electrochemistry. Electrochemistry (including voltaic cells) is a complex subject and is very important in various applications of this concept. The concept of electrochemistry is considered difficult to visualize, especially in relation to events that occur at the submicroscopic level of macroscopic phenomena and the symbolic level (Supasorn, 2015). Chatmontree et al. (2015) stated that studying electrochemistry (galvanic cells or Voltaic cells) will be fun if in the learning process students can relate the three levels of representation. The interconnection of the three levels of representation in studying electrochemistry helps students to gain a deep conceptual understanding of electrochemistry (Supasorn, 2015).

The results of the literature review show that there has been no research that examines how to teach the voltaic cell phenomenon encountered in the laboratory, starting with thinking about how to make a hypothesis and proving the hypothesis through laboratory investigations and evaluating it by linking the three types of representation. This thinking skill is one indicator of inference skills in critical thinking skills with the descriptor making inductions and considering inductions. Therefore, this research further applies the

development of voltaic cells by linking the three levels of chemical representation as an effort to improve skills in making inductions and considering inductions. Therefore, the aim of this research is to improve students' skills in making inductions and considering inductions through mental model-based voltaic cell laboratory activities. Apart from that, this research also aims to determine the advantages and limitations of the learning that has been implemented.

## **THEORETICAL REVIEW**

### ***Understanding Skills***

Skills or abilities are always mentioned as skills possessed by a person. Talking about skills, there are indeed many different abilities that each person has. Referring to Elisa and Karim (2022), it is stated that this is different from Dunette's opinion which means that skills are a person's thoughts, whereas the skills possessed by other people are a form of process of gaining knowledge that is obtained through the process of practice, training or through varied experiences. Furthermore, The definition of skill according to Gordon is the ability possessed by a person. Where the abilities they have are in the form of implementation of the work implementation system or activities. The skills that Gordon refers to can emphasize experiences or learning processes that have been learned (Elisa and Karim, 2022).

### ***Critical Thinking Skills***

The skill of making inductions and considering inductions is a critical thinking skill that is very important for students to be able to successfully face a dynamic and complex world. Quoting Fuadi et al., (2016) Critical thinking skills are a core ability so a teacher needs to teach them and develop them in the learning process.

Referring to Ennis (1996:365), critical thinking is a process that aims to make reasoned decisions about what one should believe and what one should do. Therefore, students are expected to have critical thinking skills as basic provisions, so that in the learning process a teacher needs to train and develop critical thinking skills in their students (Fuadi et al., 2016).

### ***Volta Cell Phenomenon***

Voltaic cells are electrochemical cell in which chemical energy from spontaneous redox reactions is converted into electrical energy. An example of a voltaic cell circuit consisting of Zn metal dipped in a  $Zn^{2+}$  ion solution and Cu metal dipped in a  $Cu^{2+}$  ion solution (Setyana, 2020). Likewise, Fatih (2022) revealed that A voltaic cell is a change that occurs from a chemical reaction into an electric current.

Voltaic cells are The opposite of an electrolysis cell, which is capable of converting electrical energy into chemical energy. Apart from that, it was also an electric current that was first discovered, through an inventor named Galvani and Volta himself. This cell can produce electricity because of redox which appears spontaneously, meaning that voltaic cells can convert chemical

energy into electrical energy. The potential amount of electricity that a voltaic cell can produce can be determined using a tool called a voltmeter or potentiometer. This cell consists of two electrodes, both of which are connected and can produce electricity. Apart from that, it can also function as a salt bridge to the electrolyte solution where the electrode is located (Sampoerna Acamdey, 2022).

The working principle of a voltaic cell is the separation of the redox reaction into 2 parts, namely the oxidation half reaction at the anode and the reduction half reaction at the cathode. The anode and cathode are immersed in electrolyte and connected by a salt bridge and an outer circuit (Setyana, 2020). Based on the explanation above, it can be concluded that the Voltaic Cell is a device that can produce electricity based on electrochemical redox reactions.

## METHODOLOGY

This research uses mental model-based learning adapted from Albaiti et al. (2017). This research design is a weak experimental design, one group pretest posttest design (Fraenkel and Wallen, 2012) with a sequence of research activities, namely giving an initial test, treatment, and giving a final test. A total of 12 (twelve) students who contracted the Basic Chemistry II course at a university in Papua were involved in this research. The research instruments include description tests, observation sheets, student worksheets, and questionnaires. The description test is used to analyze induction making skills and consider student induction which is calculated using the N-gain value (Hake, 1998). Each question item relates the macroscopic, submicroscopic and symbolic levels. The test instrument was validated by two experts, one in the field of chemistry education and the other in the field of physical chemistry. The results of the validity test showed that the two questions were valid and the reliability of the questions was 0.65. Critical thinking skills for descriptors making inductions and considering inductions are adopted from Ennis (Costa, 1985). The voltaic cell practicum carried out by students used Cu-Pb and Cu-Fe electrodes. From the results obtained, each sample was carried out by 2 (two) different groups. Each group consists of 3 (three) students. Grouping students based on the similarity of their initial mental models as seen from the student's hypothesis formulation on the worksheet. The mental model-based learning stages in studying the voltaic cell phenomenon are presented in Table 1.

**Table 1 Stages of Voltaic Cell Practices Based on Students' Mental Model**

<b>Stages of learning</b>	<b>Students Activities</b>
Engagement phase	Students were given voltaic cell phenomena to create cognitive conflict and motivated them to conduct practical activities.
Exploration phase	Students developed hypotheses (if.....then.....) based on the issues contained in the passages individually and evaluated each hypothesis, selecting hypotheses to be tested.
Explanation phase	Students designed a voltaic cell laboratory activities to test the hypotheses that had been formulated. Having decided upon the experimental method to be used. They made observations and measurements to collect data.
Elaboration phase	Students made discussions about anything they found out

in the investigation. Analysis of the laboratory results allows for hypotheses to be rejected or retained. Lecturer helped in facilitating class discussion in the next meeting. During the in-class discussion, students of the group should be responded.

In this research, to support the existing data, a literature search (library research method) was also carried out (Idris et al., 2021; Ilham et al., 2021; Tokang and Yumame, 2023). Where the data taken is related (relevant) to the topic being studied (Tebay and Ilham, 2023). The data sources for this type of library research are from reading sources (literature), such as books, journals, papers, online platforms and other library sources (Renyaan, 2023; Ilham and Dian Indri Yunita, 2022).

## RESULTS AND DISCUSSION

This research focuses on examining the skills of making inductions and considering the results of the induction distributed in two essay questions. Based on the calculation results, the average percentage of the initial test score, final test and N-Gain of prospective chemistry teachers was obtained for the descriptor of making induction and considering the results of induction in redox reaction materials that produce electricity as presented in Table 2.

**Table 2. Average Initial Test Score, Final Test, and N-Gain Prospective chemistry teachers in the Descriptor of Making Induction and Considering the Results of Induction of Redox Reaction Matter that Produces Electricity**

No	KBK descriptor	Code	Question Number	Average (%)		
				Initial Test Scores	Final Test Score	N-Gain
1.	Making inductions and considering inductions	CBC 1a	1	15.00	60.83	53.06
		CBC 1b	2	14,17	76.67	74.44
Average				22.09	68.75	63.75

The N-gain descriptor data for making induction and considering the induction of prospective chemistry teachers as presented in Table 2 is in the medium category (Fyneweever, 2008). Liliarsari (2005) explains that critical thinking skills are thinking skills to analyze arguments and generate insight into each meaning and interpretation, to develop cohesive and logical reasoning patterns, understand the assumptions and biases that underlie each position. Finally, you can provide a presentation model that is trustworthy, concise and convincing. Critical thinking skills are skills reasonable and reflective thinking and focused on making decisions about what prospective chemistry teachers do or believe. In line with this, there is an increase in the critical thinking skills (KBK) of prospective chemistry teachers for the descriptors that are the focus of the research.

In the engagement and exploration phase, the descriptor makes inductions and considers the dominant inductions improved by prospective chemistry teachers to be able to formulate hypotheses about the voltaic cell phenomenon. In the explanation phase, the descriptor makes inductions and considers inductions which are also dominantly improved by prospective chemistry teachers so that they can design practical procedures on voltaic cell material for each hypothesis that will be tested in the laboratory. Apart from that, the descriptor makes observations and assesses the dominant observation data that is improved by prospective chemistry teachers. However, this is not the focus of the study. In the elaboration phase, the descriptor decides on an action that is dominant for prospective chemistry teachers to discuss voltaic cell data obtained in the laboratory but which is not the focus of the study. Each descriptor of critical thinking skills developed in prospective chemistry teachers links all three levels of representation.

This research uses Science Writing Heuristic (SWH), adapted from Hand & Choi (2010) which facilitates improving the critical thinking skills of prospective chemistry teachers through activities in the laboratory. SWH is a practicum report template. This SWH approach can develop three modal forms, namely verbal and visual modes, and symbolic. The verbal mode describes entities and the relationships between them in written form. Symbolic mode consists of chemical symbols and chemical formulas, chemical equations, as well as mathematical expressions. Visual mode uses graphs, diagrams, and drawings. In line with this, the use of "representation codes" is the main task for students in learning (Hand & Choi, 2010). Stephenson & McKnight (2016) stated that the SWH practicum approach can improve students' critical thinking skills when compared to traditional approaches. Stephenson & McKnight (2016) stated that SWH can guide, build and improve students' critical thinking and reasoning skills.

A questionnaire for prospective chemistry teachers was used to find out the responses of prospective chemistry teachers about this lecture. The results obtained can be used to analyze the advantages and limitations of learning. The prospective chemistry teacher questionnaire is divided into two parts, namely closed and open questionnaires. The closed part of the questionnaire covers three aspects, namely the learning process, thinking skills and the impact of this lecture model. The responses of prospective chemistry teachers to this lesson are presented in Table 3. The results obtained show that only 1 (one) prospective chemistry teacher disagrees that this practicum model is very challenging and fun.

**Table 3. Responses of 12 Prospective Chemistry Teachers on Closed Questionnaire**

Aspect	Statement	Number of Respondents	
		Agree	Disagree
Learning process	The lectures I attended trained me to formulate hypotheses by linking the three levels of representation	12	0

Aspect	Statement	Number of Respondents	
		Agree	Disagree
	The lectures I took trained me to be able to design a practicum	12	0
	The lectures I attended provided the opportunity to prove the hypothesis I formulated	12	0
	This lecture trained me to analyze and discuss the findings obtained by linking the three levels of chemical representation	12	0
	This lecture provides a new perspective in preparing a practicum report	11	1
	This lecture is very challenging and fun	10	2
	Lectures like this should be applied to other courses	9	3
Thinking skills	I am more critical in solving problems	10	2
	The lectures I attended provided an opportunity to express opinions	10	2
Impact	The lectures I took encouraged me to work together in groups to solve problems	12	0
	This lecture increased my sense of responsibility towards lectures	12	0
	This lecture helped me to understand chemistry better	12	0

Almost all prospective chemistry teachers gave positive responses (agree) in answering statements in the three aspects of the questionnaire, namely the learning process, thinking skills, and the impact of practicum. The open questionnaire covers three aspects, namely benefits, shortcomings, and suggestions for improving this learning. The responses of prospective chemistry teachers in answering open questionnaire questions are presented in Table 4. Based on the responses of prospective chemistry teachers in the open questionnaire, in the practicum report, it is necessary to rewrite the hypothesis formulation, tools and materials as well as practicum work steps so that the practicum report becomes a unified whole.

**Table 4. Responses of 12 Prospective Chemistry Teachers to the Open Questionnaire**

Aspect	Response from Prospective Chemistry Teachers
Benefit	<ul style="list-style-type: none"> <li>• Learn to design your own practical procedures with a group.</li> <li>• Learn to make the necessary solutions.</li> <li>• It is easier to understand the material and increases curiosity.</li> <li>• More responsible, independent, trained to think critically.</li> <li>• Gain experience to formulate hypotheses and prove them.</li> </ul>
Lack of practical activities based on mental models	<ul style="list-style-type: none"> <li>• There is a lack of cooperation in groups because this practicum model is something new for second semester students.</li> </ul>
Suggestions for improving this practicum	<ul style="list-style-type: none"> <li>• The lack of knowledge of basic concepts can hinder the practicum, so it is necessary to consolidate the prerequisite material first.</li> </ul>

Based on the results of the analysis of answers to the initial and final tests, worksheet entries, practical reports, as well as the results of prospective chemistry teacher questionnaires and observation results during the implementation of the lesson, several advantages and limitations of implementing this lesson can be described. The advantages of lectures are (1) cAlon chemistry teachers do practical work with different chemicals (one sample is studied by two different groups). (2) This practicum trains prospective chemistry teachers to be able to formulate hypotheses by linking the three levels of representation, test hypotheses by designing their own practicum procedures. They also learn to prepare the necessary tools and materials themselves. When in a problem solving situation, students build mental models based on their knowledge schema for certain purposes. Students can explore and examine mental models to describe and explain the properties of a system. They are able to stimulate action in the imagination (for example carrying out thought experiments). They are able to test hypotheses on mental models for inference and prediction by adding additional proportional representations to mental models (Greca & Moreira, 2002; Seel et al., 2008; Ramadas, 2009). The function of mental models is similar to computer simulations because mental models provide simulations in the learner's mind by processing input to predict outcomes (Korhasan & Wang, 2016). (3) This practicum can improve skills in making inductions and considering inductions for prospective chemistry teacher students.

The limitations of this learning are (1) groups of prospective teachers who have similar initial mental models with low basic abilities will need more guidance from lecturers. The process of using, constructing and reconstructing their mental models is slower than groups with better abilities. Several research results show that different students' abilities construct and use mental models in different and varied ways (Jansoon et. al, 2009; Wang & Barrow, 2010). (2) This practicum requires more time for each material compared to verification practicum.

### **CONCLUSIONS AND RECOMMENDATIONS**

Learning voltaic cells based on students' mental models can improve students' skills in making inductions and considering inductions. The advantage of this learning is that one sample is used by two different groups and students are trained to formulate and test hypotheses by designing their own practical procedures. The limitations of this practicum are that the group of practitioners who have weak basic abilities need more guidance and this learning takes a long time compared to verification practicum. This research has implications for the need for students to provide explanations at the submicroscopic and symbolic level when studying macroscopic phenomena regarding chemical concepts.

### **FURTHER STUDY**

This article is the result of initial research, so there is a need for further research on the same subject, but in a different generation. This aims to determine the level of students' critical thinking skills related to the Volta Cell Phenomenon.

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