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STUDENTS' CHEMISTRY MULTIPLE REPRESENTATION ABILITY IN VOLTAIC CELL MATERIALS

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ABSTRACT

Multiple representation ability is a student's understanding of describing a concept at three chemical representation levels: macroscopic, submicroscopic, and symbolic. This ability represents a complete understanding of chemistry, so every teacher needs to know. This research was conducted to analyze students' multiple representation abilities in voltaic cell material using the Predict-Observe-Explain (POE) diagnostic test. This study uses a qualitative descriptive method to obtain an overview of the ability of multiple representations naturally. The instrument uses the POE diagnostic test, has been validated by five validators consisting of lecturers and chemistry teachers and has been tested to obtain instrument legibility. The research subjects involved 34 class XII high school students who had studied voltaic cell material. The findings of the ability profile of multiple representations include (1) the concept of voltaic cell construction; most students (32.35%) are able to understand the constructs at the macroscopic and symbolic levels accompanied by explanations at the submicroscopic level that are not correct, (2) the concept of calculating values standard cell potential, as many as 44.12% of students were able to observe (macroscopic) and calculate (symbolic) the standard cell potential value accompanied by an inaccurate submicroscopic level explanation, (3) most students (32.35%) were not correct in explaining cell voltaic in alkaline batteries at the macroscopic and submicroscopic levels accompanied by writing at the appropriate symbolic level, and (4) the concept of corrosion, most students (35.29%) were able to explain corrosion phenomena at the macroscopic and symbolic levels accompanied by explanations at the submicroscopic level which less correct.

Keywords: Multiple representation, POE, Voltaic cells.

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1. INTRODUCTION

Chemistry is part of the Natural Sciences which studies matter, including its characteristics, changes in matter and the accompanying energy (Silberberg, 2017; Brown et al., 2002). This requires students to understand and explain how a phenomenon occurs in their environment. The explanation of a phenomenon in chemistry is represented at three levels: the macroscopic, submicroscopic and symbolic levels. The macroscopic level describes phenomena and facts that occur in everyday life, for example, observing colour changes; The submicroscopic level is the unobserved or described level at the particulate level that is represented by the arrangement of atoms, molecules, and ions; while the symbolic level is used to represent phenomena in the form of chemical symbols, formulas, chemical equations (Chen et al., 2019; Harza et al., 2021; Lin et al., 2016). Thus, many students think chemistry is complex because the explanation at the particulate level makes concepts abstract and challenging to understand. Because these representations are abstract and cannot be seen directly by students, the symbolic level has many abstract symbols for students (Chandrasegaran et al., 2007). This causes an imbalance in students' understanding at three levels of representation, resulting in students having difficulties relating chemical concepts to phenomena that occur in everyday life (Jansoon et al., 2009).

Several factors cause the difficulties experienced by students in connecting the three levels of representation; for example, learning chemistry at school does not present the three levels of chemical representation as a whole and assumes that students can connect the symbolic level with the submicroscopic level independently (Wang, 2007). Therefore, there is often a jump in understanding the concepts experienced by students from the macroscopic level directly to the symbolic level without understanding the processes that occur at the submicroscopic level. This can generate misconceptions in learning (Brandriet & Bretz, 2014; Harza et al., 2021), for example, misconceptions in relating phenomena that occur with explanations at the submicroscopic level (Mulford & Robinson, 2002). Another case study showed that high school students had difficulty understanding the submicroscopic level of ion balance in weak acids, weak bases, hydrolysis of salts, and buffer solutions (Sopandi & Murniati, 2007).

The teacher's knowledge of students' multiple representation abilities at the beginning of learning is fundamental because the data can be used as a reference for determining learning strategies that follow students' prior knowledge adjusted to their education level. Because the more information or knowledge students receive during the learning process, the ability to multiple representations will be different from before. This is because students' understanding could be more stable, accurate, consistent and constantly changing when more information is obtained or recalled (Talanquer, 2011; Puji Cahyani & Sutrisno, 2018). Information about students' multiple representation abilities can be explored in various ways, including a diagnostic test (Wang, 2007). Some of the instruments that are often used include multiple-choice tests (Brandriet & Bretz, 2014; Puji Cahyani & Sutrisno, 2018), two tier multiple choice test, open questions, interviews with guiding questions (probing), interviews with using pictures or models, interviews with presented problems (Delisma et al., 2020; Ramnarain & Joseph, 2012), Interview about Event (IAE) models and Prediction-Observation-Explanation (POE) models (Fatihah et al., 2022; Rahmi et al., 2020). Each of these instruments has strengths and weaknesses.

The POE diagnostic test was used as an instrument in this study because it can spur students to make predictions about a phenomenon and test their hypotheses accompanied by explanations (Fuadi et al., 2020). This technique requires students to carry out the first activity in predicting (predict) the results of several events presented accompanied by reasons, secondly explaining the observations made (observe), then adjusting the two and providing an explanation regarding the prediction activities and observations made (explain). (Fatihah et al., 2022; Fuadi et al., 2020; Rahmi et al., 2020). The prediction stage requires students to use their prior knowledge in giving answers or opinions spontaneously. After that, students are trained to communicate the relationship between predictions and the observations' results. When predictive answers and observations are inconsistent, the importance of student explanations is explored.

Several researchers have recorded students' misconceptions about electrochemical material, especially in the voltaic cell material, which revealed that students have difficulty using standard reduction potentials to predict spontaneous and non-spontaneous chemical reactions (Sanger, 1997; Berger, 2019), difficulty understanding currents flows through electrolyte solutions and salt bridges and the mechanism of electron transfer (Ceyhun & Karagolge, 2005; Dindar et al., 2010). While many students can solve quantitative electrochemical problems, only a few can answer qualitative questions regarding conceptual knowledge of electrochemistry (Ogude & Bradley, 1994; Rahayu et al., 2011). Thus, to find out in more detail students' understanding of connecting three chemical representations in voltaic cell material, information is needed to reveal the profile of multiple representation abilities possessed by students in the voltaic cell material using the predict-observe-explain (POE) diagnostic test.

2. METHODS

Qualitative descriptive research is used in this research to provides an overview of the happening phenomenon or can also describe the situation and its development (Arifin, 2011). Qualitative research methods are often referred to as naturalistic research methods because research is carried out in natural conditions (natural settings) where research is carried out using natural objects. Natural objects develop correctly, are not manipulated by researchers, and the presence of researchers does not affect the dynamics of the object being studied (Creswell, 2014; Sugiyono, 2015). This means that researchers describe various student abilities as they are without manipulating learning with voltaic cell material.

The research instrument uses POE diagnostic test, in the form a worksheet, to assess students' multiple representation abilities in voltaic cell material. The test is in the form of descriptive questions. Each student is given four questions regarding the basic material of voltaic cells. The first question concerns a voltaic cell circuit that produces an electric current. The second question calculates the cell potential value produced by a voltaic cell. The third question concerns the symptoms or processes of voltaic cells in alkaline batteries. The fourth question is about the factors that affect corrosion in everyday life. Each question consists of 3 phases: prediction, observation, and explanation. The questions related to the prediction phase include questions that reveal students' initial abilities at the submicroscopic and symbolic levels. The second phase is observation, referring to the student's ability at the macroscopic level to record the results of experimental video observations or observed images. In the explanation phase, students are asked to explain experimental phenomena and their predictions. Students' answers at the explanation stage show students' ability to connect the three levels of chemical representation so that in a given problem, there is a relationship between the three levels of chemical representation. The instrument was validated by five people consisting of lecturers and teachers, and testing was carried out on 16 students to determine their readability.

In descriptive research, the first step is data preparation. The data obtained were in the form of student answers which were analyzed for their suitability with the answers according to the theory of experts (Elliot & Timulak, 2005). The student responses were grouped based on the similarity of student responses in the prediction, observation and explanation phases (Sendur, 2010). Response categories consist of correct responses (C), partially correct (PC), wrong (W) and no answers (NA). Correct (C), that is, if the student can meet all the criteria contained in the correct response; partially correct (PC), that is, if the student only meets some of the correct response criteria; wrong (W), that is if the student's response does not meet the correct response criteria at all and no answer (NA), in which case the student cannot provide an answer. The results of grouped student responses formed a profile pattern of multiple representation abilities in voltaic cell material. Students' answers to each question showed students ability to understand three chemical representations, namely the macroscopic, submicroscopic, and symbolic levels.

3. RESULTS AND DISCUSSION

Students' ability to link three levels of representation on voltaic cell material which is divided into four main concepts, namely the construction concept of voltaic cells that produce electric current, calculation of the magnitude of the standard cell potential value produced by a voltaic cell, explanation of the process of voltaic cells in alkaline battery cells and the factors that influence the phenomenon of corrosion as well as propose ideas or ideas to overcome them. The students' multiple representation ability on the construction concept of a voltaic cell that can produce an electric current from a spontaneous reaction is revealed by using the POE diagnostic test questions, which require students to analyze four series of voltaic cells according to figure 1.

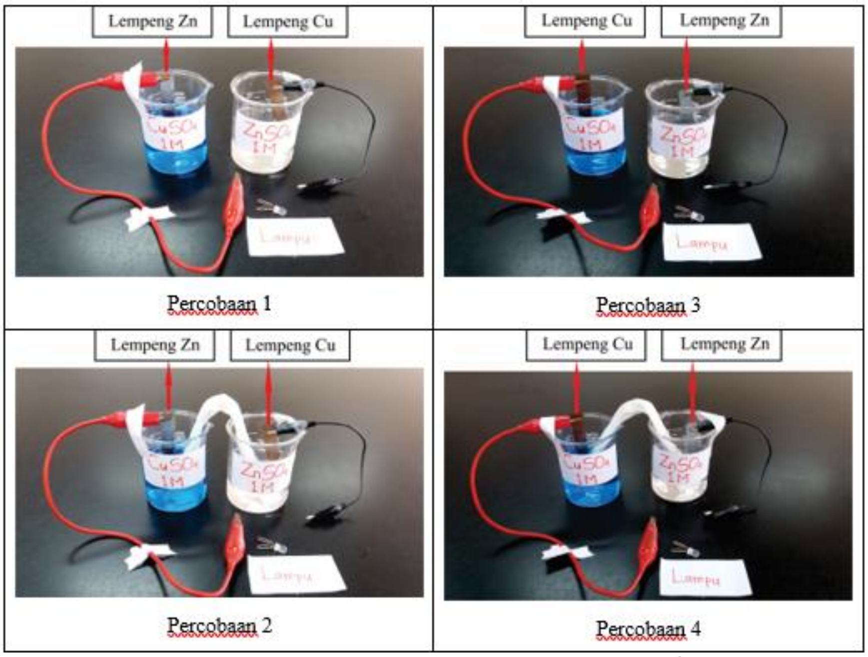

Figure 1. Series to Predict the Correct Construction of Voltaic cell

In the construction concept of a voltaic cell that can produce an electric current, seven groups of multiple representation ability profiles were found from 34 students who were spread according to Table 1.

Table 1. Profile of Multiple Representation Capability in Voltaic Cell Construction

		Submicroscopic (%)					
		C	PC	W	NA		
Macroscopic (%)	C	23,53	32,35			C	Symbolic (%)
		8,82	11,76			PC	
						W	
						NA	
	PC		5,88			C	
			11,76			PC	
					5,88	W	
						NA	
	W					C	
						PC	
						W	
						NA	
	NA					C	

		Submicroscopic (%)					
		C	PC	W	NA		
						PC	
						W	
						NA	

The analysis results show that students with all types of patterns with multiple representation abilities can generally write down equivalent redox reaction equations in voltaic cells. On the other hand, students found difficulties in general. Namely, students could not explain the construction concept of a voltaic cell that can produce an electric current at the Submicroscopic level, as indicated by the highest percentage of students, 32.35%. Students needed to be more precise in determining the direction of electron flow and explaining the function of salt bridges related to the number of ions in the electrolyte solution. For example, students are wrong in determining the direction of the flow of electrons in a voltaic cell circuit in that electrons flow from the cathode to the anode and are not precise in explaining the mechanism of the salt bridge. It was even found that students did not explain the processes that occur in voltaic cells at the Submicroscopic level. This finding aligns with several studies that state that the most difficult level in learning chemistry concepts is the Submicroscopic level (Berger, 2019; Harza et al., 2021; Rahayu et al., 2011). This level explains the atomic theory of matter, including material particles such as electrons, atoms and molecules that are viewed at an abstract molecular level. Submicroscopic level is difficult to accept as something real because it cannot be sensed directly (Chittleborough, 2004). Its principles and components are accepted as accurate and depend on the atomic theory of matter. That is, the Submicroscopic level is stated to be correct as long as the underlying atomic theory is considered correct by chemists.

Furthermore, students' multiple representation abilities on the concept of the resulting cell potential value were revealed by using the POE diagnostic test questions, which required students to calculate the cell potential value resulting from a series of voltaic cells based on known standard reduction potential value data. In this concept, five groups of multiple representation ability profiles were found from a total of 34 students who were spread according to table 2.

Table 2. Profiles of Multiple Representation Ability on Cell Potential Values

		Submicroscopic (%)					
		C	PC	W	NA		
Macroscopic (%)	C	41,18	44,12	2,94	2,94	C	Symbolic (%)
						PC	
			8,82			W	
						NA	
	PC					C	
						PC	
						W	
						NA	
	W					C	
						PC	
						W	
						NA	
	NA					C	
						PC	
						W	
						NA	

The results of the analysis showed that students in these five groups were all able to correctly observe the cell potential values generated in the experimental video. Likewise, at the Symbolic level, almost all students are able to calculate the cell potential value produced by a voltaic cell based on known standard reduction potential value data. Only 8.82% of students were unable to calculate the resulting cell potential value. If we dig deeper at the submicroscopic level, there are almost the majority of students, namely 44.12% of students, have an inaccurate understanding of determining the species that are undergoing oxidation and their oxidation potential values and the species that are experiencing reduction and their potential reduction values based on standard reduction potential value data. Provided determines the reduction and oxidation potential values of the standard electrodes. This shows that quantitative abilities in calculations are generally easily understood by students compared to qualitative understanding, which is conceptual (Ogude & Bradley, 1994; Rahayu et al., 2011). For example, students are able to determine the species that have undergone oxidation and their oxidation potential values and the species that have experienced reduction and their potential values of reduction based on the standard reduction potential value data that has been provided. Based on the known standard reduction potential data as follows:

$$Cu^{2+}(aq) + 2e^{-} \rightarrow Cu(s) \qquad E° = +0{,}34\ V$$
$$Zn^{2+}(aq) + 2e^{-} \rightarrow Zn(s) \qquad E° = -\ 0{,}76\ V$$

The species that undergo the reduction reaction have a higher standard reduction potential. The species that undergo the oxidation reaction have a smaller standard reduction potential (Silberberg, 2017; Brown et al., 2002).

Furthermore, students' multiple representation abilities on the concept of voltaic cells in alkaline battery cells are based on the pictures that have been observed. This requires students to explain the processes that occur in alkaline battery cells starting from the components, the reactions that occur and the resulting cell potential. In this concept, seven groups of multiple representation ability profiles were found from a total of 34 students who were spread according to table 3.

Table 3. Profile of Multiple Representation ability of Voltaic Cells in Alkaline Battery Cells

		Submicroscopic (%)					
		C	PC	W	NA		
Macroscopic (%)	C	23,53	2,94			C	Symbolic (%)
						PC	
						W	
						NA	
	PC	23,53	32,35		8,82	C	
						PC	
						W	
			2,94		5,88	NA	
	W					C	
						PC	
						W	
						NA	
	NA					C	
						PC	
						W	
						NA	

The analysis results showed that students in these seven groups could not directly answer the processes that occur in alkaline battery cells using only predictive questions. It can be seen from the students' answers at the prediction stage, which were still basic, but after being shown pictures of alkaline battery components according to Figure 2 in the observation stage was accompanied by standard electrode reduction potential data, most students were able to answer questions related to explaining the functions of the components in an alkaline battery cell, the redox reaction process that occurs, and the cell potential value produced by an alkaline battery cell. Only a small proportion of students (5.88%) have yet to achieve the desired competence to interpret the symptoms or processes of voltaic cells in the phenomena of everyday life in this context, namely alkaline batteries.

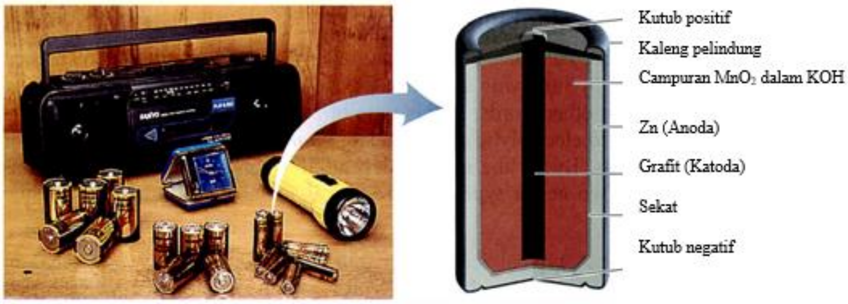

Figure 2. Alkaline Battery Components

For example, students can name the components contained in alkaline batteries and some of the functions of some of these components that are not quite right, namely MnO2 as a salt bridge. Based on theory, MnO_2 will undergo a reduction reaction, and Zn will undergo an oxidation reaction according to known standard reduction potential data (Brown et al., 2002).

Furthermore, students' multiple representation abilities on the concept of corrosion and proposing ideas to overcome them based on experimental videos observed by students. This requires students to explain the processes that occur in corrosion, the reactions that occur, the factors that influence it and ideas or ideas to overcome them. In this concept, six groups of multiple representation ability profiles were found from a total of 34 students who were spread according to Table 4.

Table 4. Profile of Multiple Representation ability on Corrosion

		Submicroscopic (%)					
		C	PC	W	NA		
Macroscopic (%)	C	8,82	35,29		26,47	C	Symbolic (%)
						PC	
						W	
						NA	
	PC		11,76	5,88	11,76	C	
						PC	
						W	
						NA	
	W					C	
						PC	
						W	
						NA	
	NA					C	
						PC	
						W	
						NA	

The analysis results show that most students can choose an experiment that will produce rust in Figure 3. So that they can analyze the factors that influence the occurrence of the corrosion process, most of them can also submit ideas or ideas to overcome the occurrence of corrosion, which means that students have reached the competency level. However, if examined in depth, most students (61.76%) need help explaining corrosion phenomena at the Submicroscopic level, especially in proposing ideas or ideas that can prevent corrosion associated with the voltaic cell concept. At the Symbolic level, most students can write the equivalent reaction equation in the corrosion phenomenon.

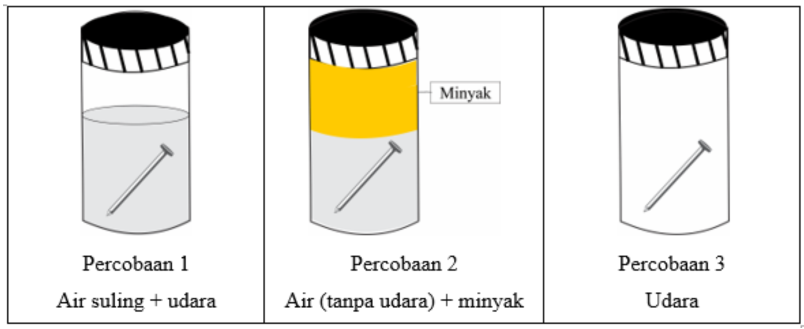

Figure 3. Corrosion Experiment Series

For example, students can find the factors that influence the occurrence of corrosion based on the video experiments that have been observed and propose ideas or ideas to overcome the occurrence of corrosion. However, students need help explaining this phenomenon at the submicroscopic level. Students can write down the redox reactions that occur at the symbolic level based on known standard reduction potential data.

4. CONCLUSION

Based on the analysis of students' multiple representation abilities on the voltaic cell, which includes the concept of voltaic cell construction, calculating the resulting standard cell potential values, the concept of voltaic cells that occur in alkaline battery cells and discovering the factors that influence the occurrence of corrosion and come up with ideas to overcome them. In the voltaic cell construction, seven profiles of multiple representation capabilities were obtained; calculating the cell potential value obtained five profiles; the concept of a voltaic cell that occurs in alkaline battery cells obtained seven profiles and the concept of corrosion obtained six profiles. The ability of students' multiple representations in connecting the macroscopic and symbolic levels, accompanied by a correct explanation at the submicroscopic level, is contained in the concept of calculating the cell potential value produced by a series of voltaic cells. In contrast, the ability of multiple representations that could be more precise at the submicroscopic level is contained in the concept of voltaic cell construction. Furthermore, the concept of a voltaic cell occurs in alkaline battery cells and the corrosion process.

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