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Design of Science Process Skill-Based Intertextual Learning on Reaction Kinetics Concept

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Abstract

The study aims to design an intertextual learning strategy with Predict-observe-explain (POE) to develop students' science process skills. The research method is Research and Development (R&D) consist of material analysis, developing indicators of science process skills, and developing learning designs. The learning design was validated by five experts. Based on experts' suggestion, intertextual-based learning activities involving three levels of chemical representation with POE learning steps to build the concept of the effect of the nature of the reactant and catalyst on reaction rates and develop students' science process skills. The strategy consists of five phenomena which are followed by three experiments and two videos as observation tools for the student. The explanation stages are guided by sets of guiding questions that involve multi-representation levels in that explanation. The product of this research is expected to be used as an alternative learning strategy that can be used by teachers to minimize the possibility of misconceptions that occur, increase mastery of concepts, and students' science process skills.

Keywords: catalyst, intertextual learning strategy, kinetics reaction, predict-observe-explain, science process skills

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1. Introduction

In general, chemistry includes abstract concepts that are considered difficult by students (Uce, 2014). According to Johnstone (1982) in (Treagust, 2003) chemists refer to chemical phenomena at three different levels of representation; macroscopic, symbolic, and submicroscopic which are interrelated. In line with Adadan (2013), that chemistry will be easier to reach if it is represented in the three levels of representation, so according to Handayanti, et al. (2015) students' understanding will be intact (Adadan, 2013; Handayanti, 2015).

On the other hand, according to Lukum (2015) chemistry is also experimental based so that involves a close relationship between theory and practice. Therefore, in the process of learning chemistry, students need skills that can assist in the discovery of the theory. Learning with process skills will make students actively involved in learning so that there is an interaction between the development of process skills and science, as well as developing the attitude of scientists in students (Yuliani, 2014). The results of Gultepe's (2015) research also show that science process skills in general have a positive effect on science teaching.

Facts according to research by Tasker & Dalton (2005), chemistry learning mostly only operates at the macro and symbolic level, so that students' understanding becomes incomplete. One of the chemistry materials that many students understand incompletely is the factors that affect the rate of reaction. This is based on the research by Handayanti, et al (2015) that only 45.83% of students understand the submicroscopic level. In addition, misconceptions are also often found in these materials, including the nature of the reactants and catalysts (Handayanti, 2015). The results of Titari & Nasrudin's research (2017) show that there are students who say that the smaller the surface area, the faster the reaction rate (Titari dan Nasrudin, 2017). For the sub-material, the effect of the catalyst on the reaction rate is the result of Kirik's research (2012) showed the misconception that occurs is that the catalyst works by lowering the activation energy with the same reaction mechanism because the reaction is fast (Kirik, 2012). In addition, the problem to find out the misconceptions on other reagent state factors other than the surface area is rarely found.

Preliminary research results show that the percentage of observing SPS aspects is 59.09%%, measuring is 50.80%, classifying is 59.34%, predicting is 72.99%, communicating is 41.98%, controlling variables is 43.85 %, making a hypothesis of 57.22%, conducting an experiment of 45.18%, interpreting the data is 67.11%, and designing an experiment is 55.08%. From these data, it was concluded that from the questions that contained nine aspects of the SPS that were tested, most of the SPS aspects of the students were still relatively low.

From the problems above, we need a solution that can improve mastery of concepts, which is making understanding complete and reducing students' misconceptions on the sub material of the effect of reactants and catalysts on reaction rates, as well as improving students' science process skills. Therefore, the basic competence of 3.6 is to explain the factors that affect the reaction rate based on the collision theory and 4.7 is to design, carry out, conclude, and present the experimental results.

The implications of the research results Wiyarsi, et al. (2018), it is necessary to use a multiple representation approach in chemistry learning (Wiyarsi, 2018). According to Chittleborough (2004), chemical representation is an important role in teaching and learning chemical concepts (Chittleborough, 2004). Intertextual learning strategy is a learning strategy that links the macroscopic, submicroscopic, symbolic, and students' experiences in everyday life (Yuliana, et al., 2015; Wu, 2003). Furthermore, Kibirige, et al. (2014) recommended that studies be conducted on other science concepts to determine the effect of Predict-Observe-Explain (POE). This is because POE is based on the constructivism learning theory which assumes that through activities to predict, observe, and explain something observed, the cognitive structure will be well-formed (Warsono dan Hariyanto, 2017). The results of Syamsiana's research, et al. (2018) also show that the POE model is effective in improving student learning outcomes on the material factors that affect reaction rates. In addition, by using the POE model, students' science process skills can also potentially increase because the learning steps; prediction, observation, and explanation, can be a place for students to develop their science process skills. This is supported by several previous studies showing the effectiveness of the application of the POE model in improving students' science process skills, including the results of research by Murezhawati (2017), and Algiranto (2019). Therefore, this study aims to develop an intertextual learning strategy with POE to improve mastery of the concept of the effect of reactant and catalyst states on the reaction rate and students' SPS. The research question in this study is how the intertextual learning strategy with POE on the concept of the effect of the nature of the reactant and catalyst on the rate of reaction has the potential to increase students' mastery of science concepts and process skills.

2. Research Method

This research uses the research and development (R&D) method which has three stages: Research and information gathering; product development planning; and initial product draft development. In stage 1, several analyzes were carried out such as an analysis of the basic competencies of class XI, three levels of chemical representation, misconceptions on the sub material of the effect of reagent and catalyst states on reaction rates, science process skills (SPS), preliminary research on SPS, and literature analysis on intertextual strategies and POE models. In Phase 2, the indicators of mastery of concepts and indicators of SPS were formulated based on the 2013 curriculum. The last stage of this research was the optimization of the practicum and development of learning strategies in accordance with the indicators of mastery of concepts and indicators of SPS based on the intertextual basis with the POE model. Data obtained from 5 validators of chemistry lecturers regarding the suitability of intertextual learning activities with POE, concept mastery indicators, and SPS indicators were analyzed qualitatively. The results of the validation in the form of suggestions from the validator were analyzed before being used for learning strategy improvement materials.

3. Result and Discussion

3.1. Material and Indicators Analysis

Concerning graduate competency standards, every primary and secondary education graduate must have competencies from three dimensions, which are attitudes, knowledge, and skills. Basic competencies on kinetics rate that must be mastered by student are explaining factors that affect the reaction rate based on collision theory. Student design, conduct and conclude, and present experimental results of factors that affect reaction rates and reaction orders. Indicators of mastery of concepts and concept labels are listed in Table 1.

Table 1. Concept Mastery Indicators and Concept Label

Concept Mastery Indicators	Concept Labels
Explain the effect of reactant properties on the reaction rate based on the collision theory	Effect of reactant properties on reaction rate
Explain the effect of surface area on reaction rate based on collision theory	Effect of surface area on reaction rate
Explain the effect of homogeneous catalysts on reaction rates	Effect of homogeneous catalyst on reaction rate
Explain the effect of heterogeneous catalysts on reaction rates	Effect of heterogeneous catalyst on reaction rate

Science process skills indicators derived from basic competencies: student design, conduct and conclude, and present experimental results of factors that affect reaction rates and reaction orders. The science process skills indicators were developed 32 indicators to include several aspects listed in Table 2.

Table 2. Aspects of Science Process Skills Contained in The Science Process Skills Indicator with Description

Science Process Skills Aspects	Science Process Skills Aspect Descripstion
Predict	Predicting can be interpreted as anticipating or making predictions about everything that will happen in the future, based on estimates on certain patterns or tendencies, or the relationship between facts, concepts, and principles in knowledge (Dimyati, dan Mudjiono, 2002).
Designing Experiments	Designing an experiment is designing activities carried out to test hypotheses, check the truth or show principles or facts that they already know (Firman, H., 2013).
Doing Experiments	Conducting an experiment is to test the hypothesis through manipulation and control of the independent variable and record the effect on the dependent variable (Zeidan, 2014).
Observe	Observing is collecting data about phenomena or events by using their senses. Observing is the basis for all other process skills (Firman, 2013).

Science Process Skills Aspects	Science Process Skills Aspect Descripstion
Applying the Concept	Applying the concept is using the generalizations that he has learned in new situations, or to explain what he has observed (Firman, 2013)
Interpreting Data	Interpreting data, which is analyzing the data obtained and organizing it by determining visible patterns or relationships in the data (Carin, 1997).
Conclude	Concluding, which is making general conclusions from facts or information (Carin, 1997).
Communicating	Skills in conveying ideas or findings to others (Firman, 2013).

Links between representations, experiences of daily life, and events in the classroom that students do can be seen as intertextual relations. Therefore, intertextual relations in the learning process can be a source for providing a complete conceptual understanding and teachers can use intertextual as a learning strategy in helping students understand chemical concepts (Zulfahmi, et al., 2021). However, the intertextual learning strategy does not have a syntax that can make learning more organized. Therefore, the predict-observe-explain (POE) learning model with its three syntaxes is used which can cover three levels of chemical representation and student experience and can also be a place to develop students' science skills.

3.2. Intertextual Learning Strategy with POE

Based on the concept mastery indicators and validated science process skills indicators, multiple representation analysis, and optimization results so that intertextual-based learning activities with the POE model can be arranged. The intertextual learning strategy with POE on the effect of the nature of the reactant and catalyst on the reaction rate was developed using five phenomena, with three learning stages; prediction, observation, and explanation.

In each phenomenon, student worksheets are used which are useful as learning media that help in the process of teaching and learning activities. In addition, worksheets can serve to write down students' initial understanding and observations, if observations are not written down during teacher activities, some students will change their observations because of listening to what others claim to have seen (White & Gunstone, 2014).

The prediction stage begins with students understanding the content of the phenomenon discourse, which aims to ensure students understand the situation before predicting. The appearance of phenomena at this stage is part of the macroscopic level. Understanding at the macroscopic level is an understanding of chemistry based on observations obtained from the environment and then digested by the senses either directly or indirectly. Observations made usually do not escape from all the activities carried out daily found in the field or those found when carrying out experiments in the lab (Sukmawati, 2019). In this study, the macroscopic level displayed in the prediction stage is everyday phenomena or phenomena in the lab. Next, students answer predictive questions individually which aim to determine students' prior knowledge. Student prediction answers must be accompanied by reasons. At this stage, it is hoped that the submicroscopic level will emerge which explains the macroscopic understanding that students have at the beginning of learning.

At the observation stage, students make observations from both demonstration videos and practical work directly. It aims to display the macroscopic level, fulfil the basic competency skills, and develop students' science process skills.

The explanation stage contains student activities to answer probing questions contained in the worksheet with teacher guidance to 'reconcile' cognitive conflicts that occur between predictions and observations, as well as to build concepts so that indicators of concept mastery are achieved. At this last stage, questions are loaded that can explore the three levels of chemical representation that are related to students' experiences in predicting and making observations. In addition to each stage in each POE cycle involving three levels of chemical representation, the explaining stage also made probing questions that have the potential to reduce misconceptions that often occur in the concept.

3.3. Intertextual Learning Strategy with POE in Sub Material The Effect of Nature of The Reactant on Reaction Rate

In the study of the sub-material of the effect of the nature of the reactant on the reaction rate, three phenomena emerged, which the phenomenon of red phosphorus and white phosphorus is reacting with oxygen, the reaction of alkali metals with water, and the reaction of calcium carbonate ($CaCO_3$) in different forms with hydrochloric acid (HCl) solution. These three phenomena were chosen because they represent the various natures of the reactants; structure, ionization energy, and surface area. In each of these phenomena, students are asked to predict, observe, and explain in order to be able to know chemical concepts based on three levels of representation, and their interrelationships.

At the prediction stage, students are asked to predict how the reaction rate of each phenomenon is, whether the same or different (whichever is faster or slower). As in the phenomenon of white phosphorus that is must be stored in water, while red phosphorus can be stored in the open air, at this stage students are asked to distinguish the difference in reaction rates if the two phosphorus are reacted with oxygen.

To prove the prediction results, students are asked to make observations. The phenomenon of the reaction between red phosphorus and white phosphorus with water, as well as the reaction of alkali metals with water is observed through videos sourced from Youtube which can be accessed at https://youtu.be/UnuW-KpQwY8 and https://youtu.be/jI__JY7pqOM whose samples are shown in Figure 1 and Figure 2. Meanwhile, the reaction phenomenon between $CaCO_3$ in the form of chips and powder with HCl solution was observed through direct experiments conducted by students.

Figure 1. Video Demonstration of the Phenomenon of Red Phosphorus and White Phosphorus

Figure 2. Video Demonstration of Reaction of Alkali Metals with Water

After the observation, students will experience cognitive conflict, it can be in the form of predictions that are different from the results of observations, or the predictions are correct, but the reasons are different. So, in the final learning stage, that is the explanation, students are asked to explain why the results of these observations can occur through the help of the teacher in the form of probing questions. These probing questions cover the macroscopic level, the submicroscopic level, and the symbolic level. In addition, questions at this stage are also made based on the results of the analysis of misconceptions that often occur in students, such as misconceptions about the surface area which are often considered the smaller the surface area, the faster the reaction rate (Titari & Nasrudin, 2017). Therefore, questions are made that can guide students to identify the surface area in question as shown in Figure 3.

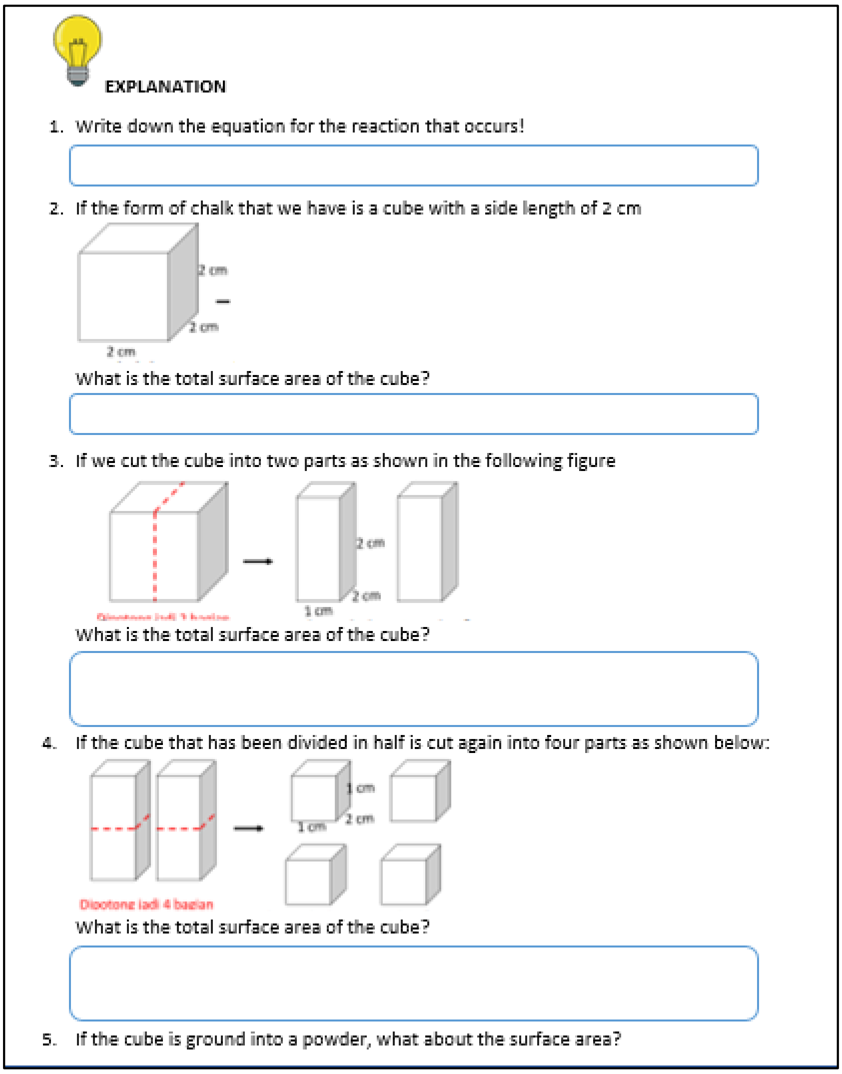

Figure 3. Some Questions about the Effect of Surface Area on the Reaction Rate in the Explanation Stage

Probing questions on explanation to explore the submicroscopic level. The submicroscopic level for the 1st phenomenon regarding the explanation that white phosphorus is more reactive than red phosphorus is due to the absence of intermolecular bonds in the molecular structure of white phosphorus so that there are more active sites which cause white phosphorus to be more likely to collide. So, Red phosphorus is more stable than white phosphorus because it has more atoms bonded together. Therefore, the active site will be less than white phosphorus which has no intermolecular bonds. The molecular structure of white and red phosphorus is shown in Figure 4. This is important to build through probing questions because the results of Rahayu's research (2022) show that students experience misconceptions and do not understand the molecular structure of red phosphorus. When students can explain the effect of molecular structure on reaction rates, but cannot describe the structure, it means that students have not been able to link the three levels of representation.

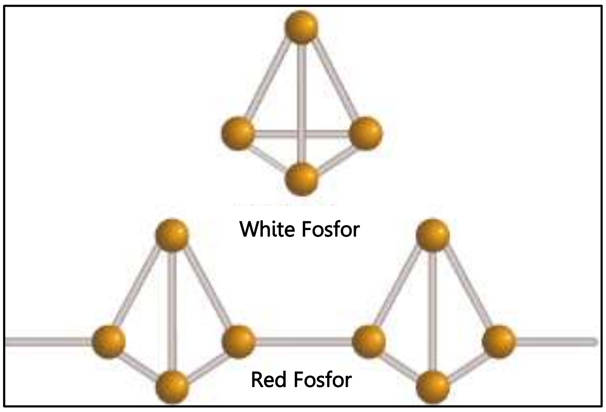

Figure 4. Molecular Structure of White Phosphorus and Red Phosphorus (Chang, 2010)

The submicroscopic level for the phenomenon of the reaction of potassium metal with water faster than sodium metal with water is because the ionization energy of potassium metal is smaller than that of sodium metal, so it is easier to release electrons to form ions (Brady, 2012; Brown, 2012). Therefore, there will be more cations at the same time reacting with water. The last phenomenon is the concept of the effect of surface area on the reaction rate. At the same mass, the greater the total surface area of a substance, the greater the number of collisions that occur, and the number of effective collisions increases, so the reaction rate is faster (Whitten, 2014; Brady, 2012; Brown, 2012; Silberberg, 2013). The symbolic level of the phenomena used in the developed strategy includes a picture of the structure of white phosphorus and red phosphorus, and a reaction equation. So, it is hoped that at the end of the lesson students can conclude the state of the reagents that affect the reaction rate, including molecular structure, ionization energy, and surface area, as well as how they affect the reaction rate.

3.4. Intertextual Learning Strategy with POE in Sub Material Effect of Catalyst on Reaction Rate

In the sub material of the effect of the catalyst on the reaction rate, the phenomenon shown is the difference in the reaction rate of the decomposition of hydrogen peroxide (H_2O_2) into oxygen (O_2) and water (H_2O) without any addition and with potassium iodide (KI) and manganese powder added. IV) oxide (MnO_2). This phenomenon can lead to diferences in reactions without a catalyst with those using homogeneous catalysts and heterogeneous catalysts. Before predictions are made, students first read discourse on the application of hydrogen peroxide in everyday life, and information about the prerequisite material they studied before, so that motivation is formed by linking the material to be learned with daily experiences and previous learning.

At the prediction stage, students were given a discourse about two Erlenmeyer flasks containing hydrogen peroxide solution, one Erlenmeyer flask was added with KI solution and the other was not. Students were asked to predict the reaction results in the two Erlenmeyer flasks to show that the reaction that occurred in the two Erlenmeyer flasks remained the same reaction, that is the decomposition of H_2O_2, then students were asked to predict which reaction was the fastest between the two Erlenmeyer flasks to determine the effect of addition of KI solution, and students are asked to predict what will happen if H_2O_2 is added after the reaction is complete in one of the Erlenmeyer flasks, the aim is to find out that the KI solution contains iodine ions (I^-) which act as catalysts which are produced again at the end of the reaction so that after Added back H_2O_2 the decomposition reaction is still going fast. This concept is very important to build because there are many misconceptions among students who think that catalysts are not involved in the reaction and are not regenerated at the end of the reaction (Rahayu, 2022).

To find out the prediction results, students with the guidance of the teacher do practical work directly. To determine the reaction rate, students will observe the foam formed, the heat produced, and the flame when the stick that has been burned is brought to the mouth of the Erlenmeyer flask as shown in Figure 5.

(a) (b)

Figure 5. (a) The Fire Does Not Expand when Brought Into Contact With An Uncatalyzed H_2O_2 Solution. (b) The Fire Expands when Brought Into Contact with An H_2O_2 Solution with An I^- Catalyst.

In the explanation stage, students answer probing questions on student worksheets to be able to explain the phenomena that occur. This probing question covering macroscopic, symbolic, and submicroscopic levels leads to the conclusion that catalysts can accelerate reaction rates by providing new alternative pathways of reactions with lower activation energies, without being consumed permanently (Petruci, 2011). Questions regarding the submicroscopic level also include what species are present in the H_2O_2 solution with and without a catalyst, as well as the difference in the activation energy diagram shown in Figure 6 which aims to reduce misconceptions about catalysts that do not react during a chemical reaction so that the catalyst does not change, even though at this level the catalyst does not change. Submicroscopic catalysts react with reactants to form intermediates and then react again to produce products.

In addition, students should also be able to explain the typical difference between homogeneous catalysts represented by KI solution and heterogeneous catalysts represented by MnO_2, which is heterogeneous catalysts can reduce activation energy by providing a surface where reactions can occur (Whitten, 2014).

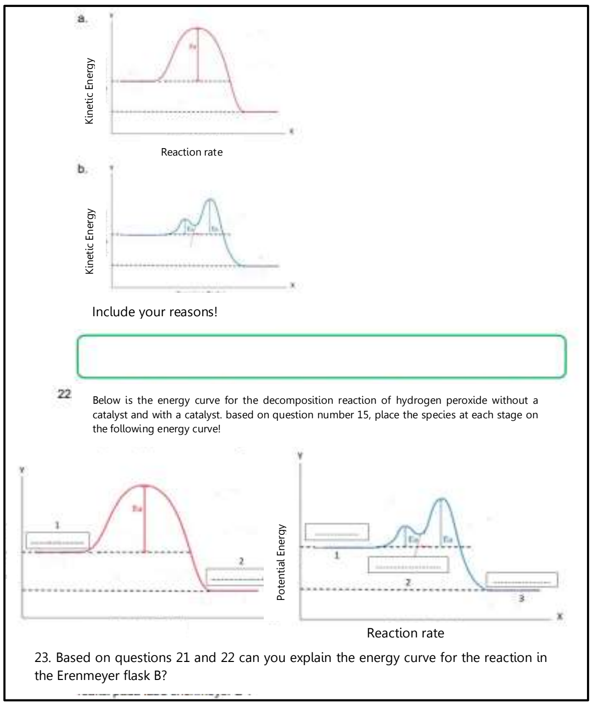

Figure 6. Several Questions at the Explanation Stage to Explain the Effect of the Catalyst on the Reaction Rate

Basic competence 3.6 requires that the determinants of reaction rates be explained based on collision theory so that in the explanation stage a question is also added regarding the relationship between lower activation energy and the faster reaction rate which is explained in the graph of the fraction of molecules that collide with the energy given to the kinetic energy shown in Figure 7. In the graph, it can be explained that the number of collisions that produce kinetic energy equal to or greater than the activation energy in a reaction with a small activation energy will be more than in a reaction with a greater activation energy so that the reaction rate is faster.

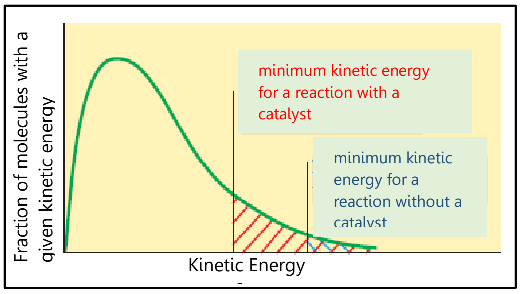

Figure 7. Graph of Molecular Fraction with Given Kinetic Energy to Kinetic Energy (Whitten, 2014)

4. Conclusion

Intertextual learning strategy with predict-observe-explain (POE) which was developed on the sub material of the influence of the nature of the reactant and catalyst on the reaction rate which has the potential to increase the mastery of concepts and science process skills of students has been validated by experts and can potentially increase the mastery of concepts based on the basic competencies and improve science process skills. The learning strategies obtained consist of 5 phenomena, that is the concept of the effect of differences in molecular structure on the reaction rate, the concept of the effect of differences in ionization energy on the reaction rate, the concept of the effect of surface area on the reaction rate, the effect of homogeneous catalysts on the reaction rate, and the effect of heterogeneous catalysts on the reaction rate. In concepts of the effect of differences in molecular structure and ionization energy on the reaction rate, demonstrations were carried out via video, while other concepts were studied by a practicum, and student worksheets were used as a tool for students in the learning process. Then the learning strategy developed involves the level of chemical representation (macroscopic, submicroscopic, and symbolic) into POE activities so that it can potentially increase students' mastery of concepts and science process skills.

The product of this research is expected to minimize the possibility of misconceptions that occur, increase mastery of concepts, and improve students' science process skills. Thus, this product can be used as an alternative learning strategy by teachers for effective chemistry learning.

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