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EXPERIMENT OPTIMIZATION ON THE REACTION RATE DETERMINATION AND ITS IMPLEMENTATION IN CHEMISTRY LEARNING TO DEVELOP SCIENCE PROCESS SKILLS

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Abstrak. Keterampilan proses dalam sains sangat diperlukan untuk membangun konsep dan pemahaman peserta didik. Salah satu upaya yang dapat dilakukan untuk mengembangkan keterampilan proses ialah dengan aktivitas belajar di laboratorium. Penelitian ini dilakukan bertujuan untuk mengembangkan keterampilan proses sains mahasiswa melalui penggunaan perangkat praktikum yang dapat mengukur laju reaksi secara kuantitatif. Eksperimen untuk mengetahui kondisi optimum dari praktikum penentuan laju reaksi pembentukan gas dilakukan untuk selanjutnya diturunkan menjadi lembar kerja. Lembar kerja yang telah divalidasi diimplementasikan kepada mahasiswa dengan menggunakan *pre-experimental design* dengan bentuk *one shot case study*. Subjek penelitian ialah 38 orang mahasiswa semester IV program studi Pendidikan Kimia UIN Sunan Gunung Djati Bandung yang mengambil mata kuliah kinetika dan kesetimbangan. Pengumpulan data dilakukan dengan menggunakan instrumen lembar kerja, lembar observasi aktivitas mahasiswa dan daftar ceklis kinerja praktikum. Hasil penelitian menunjukkan bahwa kondisi optimum praktikum penentuan laju reaksi pada variasi konsentrasi H_2O_2 sebesar 1,5 - 6% ialah penggunaan tabung reaksi sebagai reaktor, pipet ukur sebagai penampung gas, katalis KI dan MnO_2 sebanyak 0,002 mol, serta volume gas O_2 yang diamati sebanyak 10 mL. Hasil observasi terhadap aktivitas mahasiswa pada saat berlangsungnya kegiatan praktikum menunjukkan nilai rata-rata sebesar 98±4,737%, nilai ini menunjukkan bahwa mahasiswa terlibat aktif dalam kegiatan praktikum. Hasil analisis keterampilan proses sains mahasiswa pada praktikum penentuan laju reaksi pembentukan gas secara keseluruhan diinterpretasikan sangat baik dengan nilai rata-rata sebesar 88±1,785. Aspek mengumpulkan data memiliki nilai rata-rata tertinggi yang diinterpretasikan sangat baik dengan nilai sebesar 100. Aspek KPS menyimpulkan memiliki nilai rata-rata terendah yang diinterpretasikan baik dengan nilai sebesar 76.
Kata kunci: keterampilan proses sains, optimasi eksperimen, penentuan laju reaksi

Abstract. Process skills in science are needed to build students' concepts and understanding. One effort that can be done to develop process skills is by laboratory activity. This study aimed to develop science process skills of students through the use of experimental laboratory equipments that can determine the reaction rate quantitatively. Experiments were carried out to find out the optimum condition of the experiment for determining the reaction rate based on gas formation to be implemented on worksheets. Validated worksheets were implemented to students using pre-experimental design in form of one-shot case study. The subjects of this study were 38 students of Chemistry Education, State Islamic University Bandung, who took kinetics and equilibrium course. Data collection was carried out using worksheet, student activities observation sheets and performance checklist. The results showed that the optimum conditions for determining the reaction rate at variations of H_2O_2 concentrations of 1.5 - 6% were the use of the test tube as the reactor, measuring pipette as the leveling bulb, 0.002 mol of KI and MnO_2, and 10 mL of O_2 gas observed. Observations on the activities of students during the experimental showed an

average value of 98±4,737%, this value indicates that student actively involved in practicum activities. The results of the students' science process skills analysis on the determination of the reaction rate based on gas formation overall are interpreted very good with an average value of 88±1,785. The aspect of collecting data has the highest average value that is interpreted very good with a value of 100. The aspect on making conclusion has the lowest average value that is interpreted good with a value of 76.
Keywords: science process skills, reaction rate determination, experiment optimization

INTRODUCTION

Science studies three aspects; attitudes, processes, and products. The science process refers to the skills used in understanding science, such as the use of scientific methods to solve problems (Yunita, 2013). Process skills in science are needed to study and develop scientific concepts, such as thinking, reasoning, and acting logically (Farida, 2017). Therefore, as long as science learning takes place, students need to build science process skills (Gultepe and Kilic, 2015). As a part of science, chemistry is a systematic and detailed study, so that it must be understood in an integrated manner (Waldrip et al., 2010). Learning Chemistry emphasizes direct experiences through scientific processes and attitudes therefore it needs to be supported by science process skills (Irmi dkk., 2019). Science process skills can be used by students to solve complex problems (Irwanto et al., 2017) and to investigate phenomena around them which will be useful in building scientific concepts (Gultepe, 2016).

Science process skills can be built through learning process in the laboratory (Karsli and Ayas, 2014). Laboratory activities can improve the meaningfulness of learning and conceptual understanding of students (Hofstein and Kind, 2011). Thus, laboratory activities in chemistry learning become more important than conventional learning (Demircioglu and Yadigaroglu, 2011). One of the chemical concepts that are closely related to the laboratory activity is the reaction rate (Irwanto et al., 2017), where the experimental condition that affect the rate are often studied (Rodriguez et al., 2018). Unfortunately, reaction rate practicum is usually carried out qualitatively (Pratiwi, 2016), while quantitative practicum activities are really needed by students to encourage the implementation of experimental learning. It aims to improve student understanding, because research suggest that graphical representation of chemical kinetic in textbooks can make students confused and may not have adequate conceptual understanding (Seethaler et al., 2018). Thus, the activities of quantitative reaction rates practicum are needed.

Practicum of gas formation, such as hydrogen peroxide decomposition, can be used in reaction rate learning because it can demonstrate the concept of reaction rates quantitatively (Cybulskis et al., 2016). This practicum can demonstrate the fundamental concepts, including the peroxide reaction rate (Barlag, 2010), reaction enthalpy (Tatsuoka and Koga, 2013), activation energy (Sweeney et al., 2014) and has relevance to various other sciences (Cybulskis et al., 2016).

The practicum can be easier to implement with the presence of experimental tools that can determine the reaction rate quantitatively (Pratiwi, 2016). The use of experimental tools supports technical skills in the laboratory; without these skills, students can not collect and analyze data properly (Hensiek et al., 2016). In addition, research showed that the use of experimental tools can help teachers prepare and present sufficient experiment (Orwat et al., 2016). The experimental tools can also be made using tools that are easily found and simple materials (Cybulskis et al., 2016; Papai et al., 2019). Therefore, the researcher intends to conduct a study of developing experimental tools and implementing the practicum of reaction rate determination based on gas formation to develop students' science process skills.

METHOD

The method that is used in this study was pre-experimental design in the form of a one-shot case study. This method aimed to analyze the results of observations on research subjects after being given certain treatments (Sugiyono, 2017). Experiment optimization was carried out to determine the reaction rate based on gas formation before being implemented to the students.

1. Preparation stage

This stage included concept analysis, analysis of science process skills indicators, preliminary studies, instruments preparation, validation and revision of instruments and experiment optimization.

The experiment was carried out six times with a focus on the function of practicum tools and the amount of each material used during the practicum. The tools used include the reactor (test tube and erlenmeyer), connecting hose, leveling bulb (measuring pipette and pipette volume), beaker (100 mL), volumetric flask (100 mL), measuring cup, watch glass, wash bottle, stirring rod, funnel, drop pipette, analytical balance, spatula, stative, clamps, bosshead and ring. The materials that was used in this experiment are hydrogen peroxide, manganese dioxide, and potassium iodide. The arrangement of experimental equipment that was used as shown in the Figure 1.

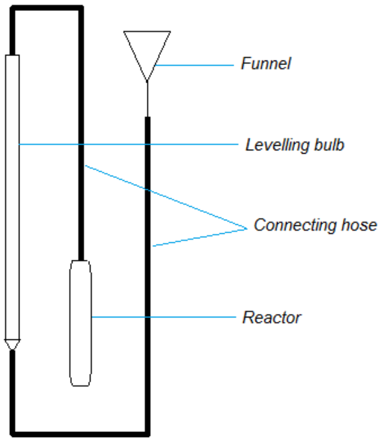

Figure 1. The arrangement of experimental equipment

Experiment 1 was conducted to determine which reactors and leveling bulb were more effective to use. In this experiment, there were two reactors tested; test tube and Erlenmeyer. Experiment 2 was conducted to determine the number of catalysts used during the practicum. This experiment was carried out using two variations in the amount of catalyst; 0.002 mol and 0.004 mol.

In experiment 3, the reaction rate was determined for the hydrogen peroxide concentration of 1%-6% using a potassium iodide catalyst. In experiment 4, the reaction rate was determined for the hydrogen peroxide concentration of 1%-6% using a manganese dioxide catalyst. The amount of KI and MnO_2 as catalyst used in the experiments 3 and 4 were based on the experiment 2. The time recorded was the time taken to form 10 mL of oxygen. Experiments 5 and 6 were conducted to determine the time needed to form 20 mL of oxygen for each catalyst used in experiments 3 and 4.

2. Implementation stage

At this stage, experimental activities were carried out to develop students' science process skills. The subject of this research is student of the Chemical Education Study Program of Sunan Gunung Djati State Islamic University which took kinetics and chemical equilibrium course with a total of 38 students. Students were put in random groups then practiced the determination of the reaction rate based on gas formation in the group. This implementation was complimented by assessments through observation sheets, practical work checklist, and worksheets. The aspect of science process skills developed in this study included formulating problems, making hypotheses, designing experiments, collecting data, interpreting data, making conclusion and communicating skills.

3. Final stage

This stage included collecting and processing data so that conclusions can be drawn regarding this research.

RESULT AND DISCUSSION

The research data were obtained through optimization results, student worksheet, student activity observation sheet and performance checklist. This data was analyzed to answer the research problem. The optimization results were used to determine the practicum activities that will be carried out. Student activity observation sheet and performance checklist were used to analyze student activity. Results of worksheet were used to analyze students' science process skills. The following is a description of each data obtained and the related discussion.

1. The optimum practicum conditions for determining reaction rate based on gas formation

Based on the experiment 1, the test tube showed a more effective result than Erlenmeyer. As for the use of leveling bulb, the measuring pipette was chosen because it can show the scale of water decreasing with good accuracy. Measuring pipette has high precision and is used to measure volume carefully (Yunita, 2013).

From the result of experiment 2, it was known that the decomposition reaction using a catalyst as much as 0.004 mol faster than the use of catalyst as 0.002 mol. The quantity of the material used affects the reaction rate. The greater the quantity, the faster the reaction takes place so that the rate becomes even greater (Gilbert, 2018). The reaction rate was too fast in the use of 0,004 mol catalyst, so the observation on the volume of oxygen produced becomes more difficult. Whereas with the use of 0.002 mol catalyst, a decrease in scale at the leveling bulb was more easily observed.

In experiment 3 and 4, determination of the reaction rate of hydrogen peroxide decomposition was carried out using a concentration variation of 1.5% - 6%, which can be said to be low. This is based on hydrogen peroxide is toxic and should not be digested (Sweeney, 2014). The amount of KI and MnO_2 as catalyst used in the experiments 3 and 4 were based on the experiment 2, which is equal to 0.002 mol. Experiments 5 and 6 were conducted to determine the time needed to form 20 mL of oxygen. The results of experiments 3, 4, 5, and 6 show that the reaction rate increases with increasing hydrogen peroxide concentration. Concentration indicates the amount of solute in a solvent or solution (Gilbert, 2018). With increasing concentration means the amount of solute becomes more and more. In line with this, the reaction rate increases with increasing concentration because the chances of collisions are higher (McMurry, 2012).

The reaction orders can be determined based on testing using hypotheses and by calculating using the rate equation. The use of hypotheses is done by plotting the reaction rate (y-axis) with [H_2O_2] (x-axis), if it is proven to be linear, it can be said that the reaction is first order. To test whether the reaction is second order, it is done by plotting the reaction rate (y-axis) with $[H_2O_2]^2$ (x-axis) (Barlag, 2010). To find out the linearity of a graph, a Microsoft Excel application can be used. After the graph is made, it can be known the value of the determination coefficient or R^2. This coefficient shows the effect of the independent variable on the dependent variable with a range value 0-1 (Ghozali, 2012). Thus, if the R^2 value is closer to 1, then the graph is increasingly linear.

The reaction orders can be determined based on the calculation using the following rate equation:

$\ln (v) = h \ln[H_2O_2] + \ln(k^I)$

So the reaction order can be known by plotting the ln v (y-axis) with ln [H_2O_2] (x-axis), where the reaction order is a gradient in the line equation (Barlag, 2010). The following Table 1 shows the recapitulation of linearity value and reaction order based on experimental results.

Table 1. Recapitulation of linearity values and reaction orders

No	Experiment	Linearity	Reaction Order
1.	3	0,95	1,1704
2.	4	0,97	1,2181
3.	5	0,88	1,3153
4.	6	0,96	1,1138

The reaction orders from the data processing obtained from the practicum are not much different from the previous research that the order of hydrogen peroxide decomposition was obtained by 1,3 ± 0,1 (Cybulskis et al., 2016). Thus, the oxygen volume observed was 10 mL; this is based on the linearity and reaction order obtained, as found in Table 1.

2. Analysis of student activity observation results

Student activities were assessed individually by observers. One observer assessed 4-5 students. During the experiment, students showed high enthusiasm. Students also showed a good cooperative attitude by dividing tasks for each group member. The result analysis of student activity observation can be seen in Table 2.

Table 2. Result of student activity observation

No	Aspects Observed	Average (%)	Interpretation
1.	Students are active in carrying out practicum	100	Very good
2.	Students are active in reporting data according to the observations in the laboratory	100	Very good
3.	Students are active in writing data according to the results of practicum	100	Very good
4.	Students play an active role in carrying out their tasks in a group	100	Very good
5.	Students are active in completing practical activities	100	Very good
6.	Students respect each other's opinions	97,5	Very good
7.	Students are active in cleaning and tidying up tools or materials that have been used	100	Very good
8.	Students complete practical activities according to the schedule	100	Very good
9.	Students collect practicum reports according to the schedule	84	Very good

No	Aspects Observed	Average (%)	Interpretation
10.	Students obey the rules in the laboratory	97,5	Very good
	Average	98±4,737	Very good

Based on the Table 2, it is known that the average percent value of student activity as a whole is 98±4,737% with very good interpretation. The lowest aspect of student activity is on the collection of practicum reports according to the schedule. Some of the factors that have been the cause of student delays are because the report is written assignment done outside of laboratory activities, and there are some students who can not collecting reports on time due to illness.

3. Analysis of students' science process skills

The aspect of science process skills developed in this study includes formulating problems, making hypotheses, designing experiments, collecting data, interpreting data, making a conclusion and communicating skills. Each aspect of the science process skills was analyzed individually, then averaged for each group. Overall, the results of students' science process skills value analysis can be seen in Table 3.

Table 3. Results of Students' Science Process Skills

No	Group	Average Science Process Skills Value							Average	Interpretation
		1	2	3	4	5	6	7		
1.	I	83	85	92	100	95	76	86	88	Very good
2.	II	80	82	88	100	96	72	84	86	Very good
3.	III	93	94	92	100	98	72	87	91	Very good
4.	IV	83	85	84	100	97	72	83	86	Very good
5.	V	76	78	88	100	97	81	82	86	Very good
6.	VI	80	81	91	100	97	94	89	90	Very good
7.	VII	83	85	86	100	91	77	84	87	Very good
8.	VIII	84	86	90	100	98	76	85	88	Very good
Average		83	85	89	100	96	78	85	88±1.785	Very good

Note:
1 : formulating problems
2 : making hypotheses
3 : designing experiments
4 : collecting data
5 : interpreting data
6 : making conclusion
7 : communicating

Students' science process skills in the aspect of formulating problems show an average value of 83 with very good interpretation. Nevertheless, there are still groups that have an average value below 80. This aspect is so important to develop because it is a fundamental skill that must be possessed before being able to learn more about the problem (Farida, 2017).

The aspect of making hypotheses interpreted very good with a value of 85. Most students could write their hypotheses in full and relevant to the formulation of the problem previously proposed. In line with this, Trianto (2012) states that students are expected to be able to make hypotheses to explain the questions they ask.

The aspect of designing experiments has an average value of 89 with very good interpretation. Designing experiments skills include skills in expressing practicum goals and principles, determining the tools, materials, and procedures used. These skills are interpreted very good because in the worksheet there are instructions for students to carry out the practicum so that students can design experiments well. Based on this, the worksheet is one of the most important teaching materials as a guide for conducting investigations and solving problems (Trianto, 2012). However, in relation to laboratory activities, the worksheet developed were not in a form of cookbook labs. Cookbook labs can make students tend to learn little although it can be highly efficient to use (Walker et al., 2016).

Skills in collecting data include observing skills. Students will not get the right data if they are not skilled in making observations. Without having good observing skills students can not collect and analyze data properly (Hensiek et al., 2016). The result of the collecting data aspect has an average value of 100 with very good interpretation.

Student performance at the time of conducting the experiment was also observed and assessed by the observer. Table 4 shows science process skills analysis results based on student experimental performance.

Table 4. Results of Students' Science Process Skills Based on Experimental Performance

No	Group	Average Science Process Skills			Average	Interpretation
		1	2	3		
1.	I	100	100	95	98	Very good
2.	II	100	100	100	100	Very good
3.	III	64	100	100	88	Very good
4.	IV	80	100	100	93	Very good
5.	V	100	100	100	100	Very good
6.	VI	100	100	91	97	Very good
7.	VII	100	100	97,5	99	Very good
8.	VIII	100	95	97,5	97,5	Very good
	Average				96,5±3,852	

Note:
1 : preparation of experimental equipments
2 : preparation of materials
3 : determination of reaction rate

Based on Table 4, the average value for student experimental performance is interpreted very good with a value of 96,5±3,852. This corresponds to the average value of the collecting data aspect that is also interpreted very good.

At the time of compiling the experimental equipment, there were still students who were confused about assembling the tools. This is because the worksheet only illustrates the practicum tools scheme and does not mention which tools will be used overall. Whereas students usually carry out practical activities by being given a guide that is so complete including the tools used (Marlina, 2011). However, students were very enthusiastic in compiling practicum tools.

The aspect of interpreting data interpreted very good with an average value of 96. Students are guided to interpret the data through the questions contained in the worksheet. This question is also intended to facilitate students in understanding the concept so that they can draw the right conclusions based on the practicum. Also, overall students can graph the relationship between reaction rates and concentration properly. Students can also graph the relationship between the rate of reaction with concentration and determine the reaction order good. It means that student has a good mathematical skills, because successful interpretation of graphic needs mathematical skills to reason about the relation between existing variables (Rodriguez et al., 2019).

In the aspect of making conclusion, the average score is 78 with a good interpretation. Compared with other aspects of science process skills, the making conclusion aspect has the lowest average value. Most students still have not made appropriate conclusions. This is because students are less able to connect conclusions with the formulation of the problems previously made (Aisyah dkk., 2017).

In the communicating aspect, obtained an average value of 85 with very good interpretation as contained in Table 3. These skills are reviewed based on laboratory reports made individually by students. Students required to report the experimental results systematically, the content of report must be good and true, and the report presents the experimental results with good and polite language (Saidaturrahmi dkk., 2019). In this study, communicating skills were carried out in the written form. Communicating skills are skills in conveying results to others in various ways (Putri dkk., 2014). This skill can also be done orally or in writing (Hidayah, 2017). Reports in written form besides being able to help improve skills in communicating can also help students improve their concepts understanding (Bahriah dkk., 2017).

Practicum reports made by students were complete and systematic. Unfortunately, in the sub-section of the discussion section, most students only mentioned the results of their observations without being explained. Some students are less skilled in explaining the results of their observations, they had difficulty in connecting data with theoretical explanations (Laelasari and Sari, 2016). Even though the ability to connect and explain observational data is one of the important aspects of science process skills that are data interpretation skills (Farida, 2017).

Overall, the development of student KPS from the results of this study was interpreted very good. In a line with that science process skills could be formed through practical activities because it involves students directly in the learning process so that it can improve the meaningfulness of learning and conceptual understanding of students (Hofstein and Kind, 2011). This is also in a line with the statement that learning in the laboratory is the most important component in chemistry study (Carmel et al., 2019). Even laboratory activities in chemistry learning are more important than conventional learning (Demircioglu and Yadigaroglu, 2011).

Also, the experiment activity for determining the reaction rate of gas formation has a simple procedure that is easy to implement in learning activities. The experimental equipment developed also consists of tools commonly found in the laboratory so that it is not difficult to find.

CONCLUSION

The experimental tools developed consist of tools that are easily found. The optimum practicum condition for determining the reaction rate based on gas formation was found in the use of the test tube as the reactor, measuring pipette as the leveling bulb, catalysts used is 0.002 mol, and the volume of O_2 gas observed is 10 mL. During the implementation of practicum, student activities are interpreted very good with an average value of 98±4,737%. This indicates that student actively involved in practicum activities. Students' science process skills overall are interpreted very good with an average value of 88±1,785. In addition, results of students' science process skills based on experimental performance also show a very good average value of 96,5±3,852. This shows that the use of the practicum can help to develop students' science process skills.

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