Improving chemical literacy on reaction rate’s topic through reflective explicit inquiry-based learning

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Abstract. Today, students faced a disruption era. For those, students need to be prepared with digital-age literacy. Chemical literacy is one of them. This research was conduct to know the level of chemical literacy of chemistry teacher’s candidates and the effectiveness of reflective explicit inquiry-based learning (REIBL) over traditional instruction (TI) on fostering chemical literacy. The subject was a sophomore in the chemistry department. This research is using the PISA framework to analyze chemical literacy. The Instruments were Chemical Literacy Test (CLT) for investigating the context, content, and competencies. While the attitude was investigated using Chemical Literacy Questionnaire (CLQ). Before learning, the level of competencies was very low (38,89). While the context was low (49,54) and so do the content (41,67). But the attitude was good (76,22). After having REIBL, context, content, and competencies were good (72,22; 77,78; and 66,67), and attitude was excellent (80,3). The results reveal that REIBL is superior to TI on improving the dimension of context, content, and competencies. But there is no difference in attitude’s average between them.

Keyword: chemical literacy, reaction rate, explicit inquiry-based learning

1. Introduction
Life in the 21st Century is remarkable by the acceleration in all aspects and complex development of the world. With these developments, people should be able to understand scientific facts and the relationships between society, science, and technology [1]. Thus the community can apply their knowledge to solve the problems. They are called a scientific literacy society [2]. In science education, scientific literacy is the main goal [3,4]. Scientific literacy could be determined by the capacity you have in applying scientific understanding, inventorying questions, and making conclusions from the data and evidence [5]. One of the scientific literacy applied in science learning is chemical literacy. Chemical literacy is understanding chemistry and the ability to apply it in everyday life [6]. Chemical literacy is an essential ability to have so that students can take advantage of nature through their science and technology [7].

Chemistry education students, as candidates for chemistry teachers are expected to have good chemical literacy. However, based on preliminary research carried out on the second-year students of chemistry education in the one of a national university, it was found that the mastery of the concept on the topic of reaction rate was still low. It indicates that students lack of understanding. The reaction rates’ concept is an elemental concept that must be mastered. Weak conceptual mastery is an indicator of low chemical literacy [8]. From this, there is a concern that many chemistry teacher candidates are not yet good chemical literacy or even fall into the category of chemical illiteracy.
Challenges to these problems make it necessary to improve learning. The lecturers must choose the right method. When they failed, it will have bad consequences for achieving learning objectives [9]. Consideration of the choice of methods carried out by the lecturers is to make it easy for students to understand the lessons. Chemical literacy could be increased by using explicit and reflective inquiry [10]. This is because it facilitates students to develop chemical literacy better through discussion and QA (question and answer) session [11]. The combination of explicit and reflective aspects can make learning more meaningful and effective [12]. This learning presents a phase of building epistemic knowledge that is very important in increasing chemical literacy. Epistemic knowledge is referred to as knowledge in constructing and analyzing important things for the process of building scientific understanding [13]. Based on these reasons, it is necessary to increase the level of chemical literacy by using a Reflective Explicit Inquiry-Based Learning (REIBL).

Before having improving learning, the lecture needs to know the chemical literacy level of students. There are some framework have been developed for this assessment. Based on OECD framework, scientific literacy is divided into four dimension interconnecting each other [5]. They are context, content, knowledge, and attitude. Context is including personal, local, and international issues about science. In this aspect, it requires a scientific explanation or investigation. Context refers to socio-scientific or contemporary issues or phenomena [14]. The second aspect of chemical literacy is knowledge. That means an understanding of concepts/contexts/vocabulary related to phenomena. It is divided into content knowledge, procedural knowledge, and epistemic knowledge. Content knowledge is related to knowledge about everything that exists on this earth that can be explained rationally and scientifically. Procedural knowledge is related to how to obtain content knowledge. Epistemic knowledge relates to the justification for the use of procedural knowledge. The knowledge aspect is part of what do people know. The third aspect is competence. In this aspect, one should be able to understand social phenomena scientifically, carry out scientific analysis and investigation. It is called “what can people do”. The last aspect is attitude. This aspect relates to how a person acts about the social phenomena it faces. It called “what do people value”.

Besides OECD, there is another framework named Shwartz et al framework [15]. Chemical literacy based on that framework is divided into four dimensions too. They are content knowledge, context knowledge, high order learning skills and attitude. OECD framework is more famous, explicit and simple [16].

2. Research Method

The experimental design used in this research is a Quasi-Experimental Design with the form of Nonequivalent Control Group Design. The subjects of this study were sophomore students at X university. In this study, the subjects of research are given a pretest. After that, the experimental class is treated using REIBL. The control class continued to use the TI. After that, both classes were given a posttest.

The independent variable was the learning model, the REIBL. The dependent variable was the chemical literacy of chemistry teacher candidates. Chemical literacy is derived into four dimensions. Each of them is compared between the experimental group and the control group. The four dimensions are context, content, competence, and attitude. In this study, there are control variables. They are the number of meetings in learning, lecture, pretest, posttest, and questionnaires. Data collection techniques using questionnaires, observation, tests, and documentation. Context, content, and competence dimensions were measured using the Chemical Literacy test (CLT) while the attitude dimension was measured using the Chemical Literacy Questionnaire (CLQ). There are three criteria used to determine the attitude of students, i.e. interest in the material, assessing a scientific approach to investigation, and awareness of the environment. The collected data was analyzed using independent t-test to examine the chemical literacy. The material tested to determine chemical literacy is the rate of reaction. At the rate of reaction, four topics are being tested, namely the determination of the reaction order using the integrated rate law, the determination of the reaction order using the initial rate method, the activation energy, and the factors that affect the rate of the reaction.
3. Results and Discussion
This study focuses on how the chemical literacy profile of chemistry teacher candidates. Besides that, it investigates the effectiveness of REIBL on chemical literacy. There are two main instruments used in data collection, namely reasoned multiple-choice questions and questionnaires. Multiple-choice tests can be used to measure chemical literacy even though the attitude aspect must be separate [14]. The first thing to do is to pretest. The results of the pretest were then tested for normality and homogeneity and test the difference between the two means to determine the position of the research subjects. Based on the SPSS test, it is known that the experimental class on the CLT got a significance value of 0.087 while the CLQ was 0.250. The control class has significant value on the CLT of 0.125 while the CLQ is 0.06. All classes have a significance of more than 0.05 on both the CLT and CLQ. Thus the two classes are normally distributed. In the homogeneity test, it was found that at the CLT, classes had a homogeneity value of 0.998 while the CLQ was 0.814. Both values are greater than 0.05. Thus it can be said that the two classes are homogeneous in both the CLT and CLQ. After that, the two mean similarity tests were carried out. This test is conducted to determine whether the initial state of the two classes of research subjects has the same thing in the initial condition especially the level of chemical literacy. The results of the SPSS test show that the 2-tailed independent sample t-test has a significance value of 0.358 on the CLT and 0.469 on the CLQ. Thus it can be said that the two classes did not have a difference in the average chemical literacy before being given treatment. Pretest data for experimental and control classes can be seen in Figure 1.

![Figure 1. The Pretest Data of Chemical Literacy](image)

Based on Figure 1, it is known the value of the four dimensions of chemical literacy before learning. They generally have the same average between the experimental class and the control class. After the preliminary test was carried out, learning was carried out in both classes. The experimental and control classes carried out learning 4 times. At the first meeting, the experimental class was given a video of the dissolving process of vitamin C tablet. From the video, students were asked to define the reaction rate. By looking at the changes in reactants, water, and vitamin C tablets into a product of vitamin C solution, students understand that the reaction rate is an increase in product concentration and a reduction in the concentration of reactants per time. After discussing the understanding of reaction rates, students are invited to observe the various reaction rates that exist in everyday life. For example, rusting and bombing reaction. Both are chemical reactions. But why did the rusting reaction run slowly but the bombing reaction lasting just seconds was able to have such an extraordinary effect? Students are invited to think about the reasons why this happens. This stage is called the exploration of phenomena. Next is question focusing. Lecture lets students explore questions and make some for focused.

The next activity is planning an investigation. Students are divided into several groups. The lecture provides worksheets to work on together. In the early part, students were asked in groups to discuss what factors can affect the reaction rate. After writing down their opinions, each group shared their
work. The lecture then provides an experimental video showing the experimental factors that affect the reaction rate. From that, students are asked to collect data. Students are also asked to identify the independent variables needed to investigate using virtual experimental data on the surface area, concentration, pressure, catalyst, and temperature. Students then design experiments to answer questions, identify materials needed to carry out investigations, draw illustrations of materials, and design for it. After that, students submit one or more hypotheses to test temporary explanations of investigation and design a chart/table to classify the collected data. They also identify the procedures that must be followed during the investigation.

The next stage is to carry out an investigation. Students are given 5 types of cases. Each case represents one factor of reaction rate. In further learning, students are asked to understand the collision theory. The next stage is building new knowledge. Students are given other cases to analyze. There are two new cases of concept application. The first case is the dilemma of choosing the type of thrush medication based on the fastest form that the body can absorb. The second case is the dilemma of purchasing floor cleaner with different concentration levels to clean toilet descaling in the shortest time.

The analysis of posttest includes mapping the percentage of chemical literacy of the research subjects, normality test, homogeneity, two mean similarity test, right side independent t-test, and N-gain test. From the posttest, it can figure out the kind of chemical literacy after learning using REIBL and TI. It can be found in Figure 2.

In general, from Figure 2 it is known that the chemical literacy of the experimental class is better than the control class, among in terms of the dimensions of context, content, competence, and attitudes. This is because inquiry-based learning by making activities related to everyday life can accommodate students' chemical literacy [1]. Also, in inquiry learning that has been implemented, accommodating epistemic knowledge is carried out. Thus students are facilitated to develop declarative, procedural, and epistemic knowledge. With the socio-scientific issues, students are also invited to act so that affective values can be built. In this way, the dimensions of context, knowledge, competence, and attitudes can be developed properly. Reflective-explicit inquiry learning is effective in improving students' conception of NOS compared to the implicit inquiry [17]. NOS or nature of science is an important part of chemical literacy.

The tests performed were the normality test, homogeneity test, two mean similarity test, right one-tailed independent t-test, and N-gain test. As a prerequisite for the hypothesized test, a normality test was performed. The results of the normality test show that the experimental class and control class in the final data are normally distributed. The results of the homogeneity test also showed that the research subjects were homogeneous both CLT and CLQ. The next activity is to test the two averages. The results of the SPSS 16.0 test show that the null hypothesis is rejected for multiple-choice with
reason, but not for the questionnaire. Based on this test, it is known that the average chemical literacy in the aspects of context, content, and competence is not the same between the experimental class and the control class. Besides, the average chemical literacy in the attitude aspect of the experimental class was the same as the control class.

The multiple-choice question test was continued with the one-tailed independent t-test to determine the average difference between the two classes after being given treatment. The results of the SPSS test show that the average chemical literacy of the experimental class is higher than the control class in terms of the dimensions of context, content, and competence due to sig. (1-tailed) is smaller than \( \alpha (0.005 < 0.025) \). Chemical literacy classes that are taught using REIBL have a greater average than classes taught using the TI because it facilitates students to develop chemical literacy better through discussion and QA (Question-Answer) session [11]. Inquiry-based learning is constructive learning in facilitating students to construct concepts independently [10]. With inquiry activities in the classroom or the laboratory, it is hoped that science learning will become a mini-experiment like what scientists do [18]. The combination of explicit and reflective aspects can make learning more meaningful and effective [12]. The learning also presents a phase of building epistemic knowledge which is very important in increasing chemical literacy. Epistemic knowledge is referred to as knowledge in constructing and analyzing important things for the process of building scientific understanding [13]. Other research also shows that learning that accommodates the development of thinking skills and concept building independently can improve students’ chemical literacy [19]. Material contextualization through the application of concepts makes educators can optimize chemical literacy, especially in the aspect of explaining phenomena scientifically, using scientific evidence, and identifying scientific issues [20].

Attitude is an important dimension in chemical literacy. This is because the attitude shows the interest and support of students on the issues given [1]. It can also be used to find out the responsibilities of students towards science issues. The percentage of attitude dimensions in the experimental class is greater than the control class. However, based on the SPSS test, it is known that there is no difference in the average attitude in the experimental and the control class. Morals, values, and attitudes require a relatively long time in the development process [21,22] so that they do not show significant changes if observations are made in a short period. Besides, the characteristics of the reaction rate are mostly using calculations. So, students must have mathematical abilities. There was no difference in the learning achievement of students who had high scientific attitudes and low scientific attitudes. The study also showed that there is no relationship between scientific attitudes and learning achievement [22,23]. The same environment in the experimental and control classes make learning have the same effect on the attitude dimension. The instrument factor also allows an effect even though it has been validated by expert validators [22].

4. Conclusion
The conclusion of this research are: Before being given treatment using REIBL, the context is in a low category (49.54) and the content too (41.67). While the competency dimension in the very poor category (38.89). The attitude dimension is at a good level (76.22). After being given the treatment, the chemical literacy of the experimental class in the context, knowledge, and competence dimensions was in a good category (72.22; 77.78; and 66.67). While the attitude dimension was in the very good category (80.3). Classes that are taught using REIBL have a higher average of chemical literacy in the dimensions of context, knowledge, and competence compared to classes that are taught using the TI. But there is no difference in attitude’s average between them.

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