Inquiry-Based Laboratory Activities on Drugs Analysis for High School Chemistry Learning

I Rahmawati1*, H Sholichin2, and M Arifin2

1 Program Studi Pendidikan Kimia, Sekolah Pascasarjana, Universitas Pendidikan Indonesia, Jl. Dr. Setiabudi No. 229, Bandung 40154, Indonesia
2 Departemen Pendidikan Kimia, Universitas Pendidikan Indonesia, Jl. Dr. Setiabudi No. 229, Bandung 40154, Indonesia

*irahmairma@gmail.com

Abstract. Laboratory activity is an important part of chemistry learning, but cookbook instructions is still commonly used. However, the activity with that way do not improve students thinking skill, especially students creativity. This study aims to improve high school students creativity through inquiry-based laboratory on drugs analysis activity. Acid-base titration is used to be method for drugs analysis involving a color changing indicator. The following tools were used to assess the activity achievement: creative thinking test on acid base titration, creative attitude and action observation sheets, questionnaire of inquiry-based lab activities, and interviews. The results showed that the inquiry-based laboratory activity improving students creative thinking, creative attitude and creative action. The students reacted positively to this teaching strategy as demonstrated by results from questionnaire responses and interviews. This result is expected to help teachers to overcome the shortcomings in other laboratory learning.

1. Introduction
Chemistry lab activities in high school, especially in acid-base titration is commonly used cookbook procedure with not real problems. Experimental activities only use materials in chemical laboratories. Whereas, many daily use materials and chemical phenomena can be used [1]. The cookbook practice will only encourage student passivity (creeping passivity) so that the level of student involvement is low [2]. Learning chemistry with conventional lab should be converted into activity that can make students actively seek their own knowledge required for competence development. In accordance with the rationalization of the development curriculum in Indonesia, namely the improvement of passive learning patterns into active-discovery learning [3].

With the result that students are not given the opportunity to have high creativity to solve various problems. Even though this concept requires the ability to think creatively in solving the problem. This will make the student a difficulty on the concept of titration, because this concept emphasizes instruction on numerical problem solving [4], and requires creative thinking skills [5]. Creativity is a high-level thinking ability that is very important for high school students. Because without creativity, students will have difficulty in solving problems and linking principles between productive and chemistry as adaptive subjects. With creativity, students will demonstrate the skills and dispositions which required to generate new ideas according to the problems faced by [6]. In addition, Paradigm of Education section of XXI Century [7], explained that one of the competencies or skills that must be
owned by 21st century students is creativity and innovation skills. Where students are able to develop their own creativity to produce innovative breakthroughs.

The learning model that is very suitable for enhancing creativity high school students is Inquiry-Based Laboratory (ILAB) in accordance with the results of previous study by Feldhusen and Treffinger [8], Dehaan [9], Yakar and Baykara [10], Amalina [11], and Sari [12]. However, study on acid-base titration using inquiry-based laboratory has not much discussed in the topic of drugs analysis. Whereas it is important to investigate, this is because the chemical properties of drugs that will not be separated from the concept of acid and base. In this study we aim to investigate whether using the inquiry-based laboratory can improve high school students’ creativity in acid base titration of drugs analysis.

1.1. Inquiry-based Laboratory and Creativity
The learning step with Inquiry-Based Laboratory (ILAB) according to Hofstein and Walbreg [13]: (1) problem identification; (2) formulating hypotheses; (3) designing experiments; (4) collecting data; (5) data analysis; and (6) make a conclusion. Creative thinking is measured following the creative thinking component of Guilford and Torrance [14], there is fluency (generating many ideas), flexibility (shifting perspective easily), originality (conceiving of something new), and elaboration (building on other ideas). While the components for creative attitude that is curiosity, imaginative, challenged by plurality, dare to take risks, and appreciative [15].

1.2. Quantitative Analysis of drugs with acid-base titration
Acid-base titration can be taught by using different learning plans. Thus, to work with ILAB, each group of students will have a real problem of drug analysis. They should get an initial volume of acid/base to be titrated and determine the percentage content of the drugs, wherein each compound are classified as acidic, basic, neutral or zwitterion [16]. An acid and base drugs can be used to determine the levels of the active substance by acid-base titration method. Because the basic principle of acid and base is the neutralizing reaction, between H⁺ and OH⁻ ion, as shown in Table 1 [17].

| Titration Type                  | Before the Equivalent Point                                      | Equivalent Point                                      |
|--------------------------------|-----------------------------------------------------------------|------------------------------------------------------|
| Strong acid – strong base       | HCl + H₂O → H₂O⁺ + Cl⁻                                           | HCl + NaOH → H₂O + NaCl                               |
| Weak acid – strong base         | HOAc + H₂O → OAc⁻ + H₃O⁺                                          | OAc⁻ + H₂O → HOAc + OH⁻                               |
| Strong acid – weak base         | B + H₂O → BH⁺ + OH⁻                                               | BH⁺ + H₂O → B + H₃O⁺                                  |

2. Experimental Method
In this study, we adopt mixed-methods by combining descriptive and experimental research with Pretest-Posttest, Nonequivalent Control Group Design. In the experimental class, the inquiry-based laboratory was used in chemistry experiment teaching. On the other hand, the students in the control class received the conventional teaching. The design of the study can be diagrammed as follows:

\[\begin{array}{ccc}
G_1 & O_1 & X_1 & O_2 \\
G_2 & O_1 & X_2 & O_2 \\
\end{array}\]

with \(G_1\) eksperiment class; \(G_2\) control class; \(O_1\) pretest; \(O_2\) posttest; \(X_1\) inquiry-based laboratory; and \(X_2\) conventional lab activity.

The subjects sampled in this study were 73 students at XI grade from pharmaceutical high school in Sumedang Indonesia. There were 34 students in the experimental class and 39 students in the control class, taken through purposive sampling technique. This study was conducted during four meetings on the acid-base titration concept, including pretest, implementation of inquiry-based laboratory, posttest, answer questionnaires and interviewed.

The following tools were used to assess the students' creativity: (1) creative thinking test on acid base titration, an essay test are used to collect information on students' creative thinking skills before

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and after the implementation Inquiry-Based Laboratory models; (2) creative attitude and action observation sheets; and (3) questionnaire and interviews of inquiry-based lab activities. Instruments used have been through expert validation and revision process to produce the right instruments to measure the research problem. Content validity ratio (CVR) of creative thinking test, showing that instruments can be used (CVR=1).

3. Result and Discussion
3.1. Inquiry-based Laboratory Design
Chemistry learning with ILAB requires a worksheet that will guide students in activities. Real problem that must be solved is to determine the percentage of drugs that are easy to find in drugstores around students. Tabel 2 shows the design of ILAB worksheet for drugs analysis.

| ILAB Activity                   | Task                               | Activity                                                                 | Purpose                                                                 |
|--------------------------------|------------------------------------|--------------------------------------------------------------------------|-------------------------------------------------------------------------|
| 1. Problem identification      | Acid-base daily lives              | Students are faced with a real-life problem, in this activity the problem will be presented is gastritic acid in ulcer. | Elicit ideas about pH, concentration, strength of acid-base, and how to overcome the pain with acid-base aplications. And to determine students motivation. |
| 2. Formulating hypotheses      | Neutralization of acid-base solutions | Students were were asked to explain their prediction about: Case#1: When you mix a strongly acidic with weakly acidic solution, does the pH of the two solutions after the mixing change? Case#2: Still with the same solution, but we will mix it with different volumes. Which component will cause the pH change to be more neutral? Case#3: How many tablets of drugs are needed to neutralize stomach acid? | To determine which basic principles students will use. To show how the various concepts are connected, and as a basis for further questions. And to determine students creative thinking skills. |
| 3. Designing experiments       | a. Acid-base titration              | Students design an experiments procedure by determining control variables, independent variables and their own dependent variables | Elicit ideas about indicators of acid and base titration, tools, materials, procedure and drugs sample to be determined. And to determine students elaboration and creative thinking skills. |
|                                | b. Indicators on acid-base titration |                                                                          |                                                                 |
| 4. Collecting data             | Acid-base titration                | Students collect data from their design experiment, as the activity of capturing the information needed to test the hypothesis. | Elicit ideas about titration type, sample preparation, volume, concentration, changing colors, end point, and equivalent point. |
| 5. Data analysis               | a. Stoichiometric reaction         | Students organize and analyze the data, connect to the hypothesis, predict, select findings are consistent with what is already known. | Elicit ideas about stoichiometric calculation in titration, concentration of solution, percentage active component of drugs and to determine students elaboration, and their creative thinking skills. |
|                                | b. Accuracy of titration results   |                                                                          |                                                                 |
| 6. Conclusion                  | Substitute chemical medicine        | Students describe and interpret the findings obtained based on the results of hypothesis testing. | To determine students elaboration, and their creative thinking skills |

In ILAB activity, students are required to be able to create something new, prepare and then assemble it in accordance with self-designed procedures. Besides that students are expected to make
the procedure different from others. The results of the student experiment design are presented in the Table 3.

**Table 3. Students experimental design of acid-base titration.**

| Group | Experimental Purposes | Active component | Sample          |
|-------|-----------------------|------------------|-----------------|
| 1     | Determine content of the active component in salicyl powder | salicyclic acid | salicyl powder |
| 2     | Determine content of the active component in vitamin C | ascorbic acid | vitamin C       |
| 3     | Determine content of the active component in aspirin | asetil salicyclic acid | aspirin |
| 4     | Determine content of the active component in ibuprofen tablet | ibupifen | ibuprofen tablet |
| 5     | Determine content of the active component in naspro tablet | asetil salicyclic acid | naspro tablet |
| 6     | Determine content of the active component in bodrex | asetil salicyclic acid | bodrex |

3.2. *Students Creativity in Drugs Analysis*

Improvement of students creative thinking obtained from the results of pretest and posttest data before and after inquiry-based laboratory implementation. Pretest and posttest results data then processed statistically by calculating the average value of the gain is normalized. Recapitulation scores creative thinking indicated on Table 4.

**Table 4. Students creative thinking score in elaboration component.**

| No | Indicator | Control Class | Posttest | Gain | N-Gain | Category | Experiment Class | Posttest | Gain | N-Gain | Category |
|----|-----------|---------------|----------|------|--------|----------|------------------|----------|------|--------|----------|
| 1  | Neutralization of acid-base solutions | 2.03 | 2.21 | 0.18 | 0.09 | Low | 2.03 | 3.53 | 1.50 | 0.76 | High |
| 2  | Application of acid base titration | 2.95 | 3.38 | 0.44 | 0.41 | Moderate | 2.79 | 3.06 | 0.26 | 0.22 | Low |
| 3  | Indicators acid base titration | 1.74 | 2.05 | 0.31 | 0.09 | Low | 2.09 | 2.97 | 0.88 | 0.30 | Moderate |
| 4a | Designing experiment | 1.64 | 1.90 | 0.26 | 0.19 | Low | 1.09 | 2.38 | 1.29 | 0.68 | Moderate |
| 4b | Accuracy of titration results | 1.05 | 1.51 | 0.46 | 0.24 | Low | 0.97 | 2.09 | 1.12 | 0.55 | Moderate |
| 5  | Substitute chemical medicine | 3.64 | 4.38 | 0.74 | 0.55 | Moderate | 3.53 | 4.35 | 0.82 | 0.56 | Moderate |

Table 4 shows the result of students’ creative thinking in generally improved. But, experimental class (0.51) has N-gain higher than control class (0.26). This proves that learning with inquiry based laboratory can improve students’ creative thinking skill. Creative thinking ability of experimental and control class produces very different results on question number 1, about neutralization of acid-base solutions. Students in the control class did not correct the previous error on pretest. This is seen from the control class students who wrote the same answer with the pretest as much as 56.76% and the students whose score decreased by 29.73%. This causes the N-gain value to be only 0.09.

In question number 1, student are given predictive questions about two different cases of acid base neutralization, CH\(_3\)COOH\(_{aq}\) and NaOH\(_{aq}\) with same concentration but different volume ratio. Student should have predicting which case will be close to neutral solution. In cases A, they are adding 8mL CH\(_3\)COOH\(_{aq}\) with 2mL NaOH\(_{aq}\), and case B shows that they are adding 6mL
CH₃COOH(aq) with 4mL NaOH(aq). Student in experiment class have been able to correcting prediction errors (91.18%) in the case after learning through inquiry-based laboratory activities. The situation is the same as the previous study [18], which states that inquiry based laboratories may improve assessment outcomes.

| Inquiry-Based Laboratory Activity | Mean | Percentage | Category |
|----------------------------------|------|------------|----------|
| 1 Problem identification         | 1.417| 70.83      | Good     |
| 2 Formulating hypotheses         | 1.472| 73.61      | Good     |
| 3 Designing experiments          | 1.250| 62.50      | Good     |
| 4 Collecting data                | 1.867| 93.33      | Very Good|
| 5 Data analysis                  | 1.417| 70.83      | Good     |
| 6 Conclusion                     | 1.250| 62.50      | Good     |
| Result                           | 1.530| 76.48      | Good     |

The next component of creativity is the creative attitude. The creative attitude aspect examined is curiosity, that is the student’s wish to ask many questions in every step of Inquiry-Based Laboratory activity. Table 5 shows that generally students creative attitude is in good result (76.48%), this proves that in Inquiry-Based Laboratory activity, students have high curiosity attitude. Many students ask questions during this lesson compared to ordinary learning. The highest percentage is in the data collection stage (93.33%), because at this step the students test the concentration of the medicine active substance by the procedure they design themselves. So the curiosity of the lab results makes many students ask their fellow questions through the discussion or to the teacher. The same as the previous study [19], whereas students who design their own experiments, spent relatively more time discussing the experiment and revisions of their work. The non-design students focused their efforts mostly on the mathematical procedure.

3.3. Student Responses to Inquiry-Based Laboratory

Inquiry-based Laboratory was first conducted in the pharmaceutical high school in Sumedang, but feedback from students who attended the class was very positive. The result show that chemistry learning before Inquiry-based laboratory implementation, mostly (52.84%) using methods that do not require student creativity. Even though, 100% students agree with statement that creativity is very important to owned by the vocational high school student. Whereas with ILAB students 100% stated that on learning ILAB their creativity is really used. This is supported by interviews stating that:

“All this time, chemistry class is only done regular learning, where students only discuss and practice with procedures like cooking recipes. In my opinion, my creativity is not needed during learning. Different from ILAB, here I am required to make my own procedures, I think this is a very interesting and fun thing. I can’t wait to try the experiment with my own procedure”

Furthermore Inquiry-based laboratory has many advantage, that is improving curiosity, students become more active, learning chemistry becomes more fun and easy to understand, making students think more deeply, correct the students mistake and helping students find new ideas.

4. Conclusion

In this paper, we have reported the implementation Inquiry-based Laboratory in drugs analysis with acid base titration improving pharmaceutical high school students creativity. Moreover, the students reacted positively to this teaching strategy as demonstrated by results from questionnaire responses and interviews.
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