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Analysis of Basic Laboratory Understanding of Science Education Students Using Pictorial-Based Instruments

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ABSTRACT

Learning chemistry is based on understanding concepts and requires laboratory understanding to test the truth of theories and discover the benefits of learning chemistry in everyday life. Laboratory understanding is an important aspect of natural sciences in schools and higher education, often linked to part of the psychomotor aspects of learning. So, teachers need to know the student's basic laboratory understanding profile before experimenting. One instrument that can be used to measure laboratory understanding is using a pictorial-based instrument. Pictures can provide a real picture of the test set. This research aims to analyze students' basic laboratory understanding using pictorial-based instruments. This research method uses quantitative descriptive. This instrument is equipped with pictures that provide visualization. The primary laboratory understandings are focused on experiments on making standard solutions from solids, making standard solutions from stock solutions, and acid-base titrations. Each trial has ten questions. Based on the analysis, it was found that the basic laboratory understanding of science students in the experiment of making standard solutions from solids with indicators tool selection, tool function, observing the meniscus in a measuring flask, and data processing, respectively have a correct answer score percentage of 64%; 70%; 71%; and 45%. The experiment in making standard solutions from the stock solution (dilution) with indicators tool selection, tool function, observing the meniscus in the goiter pipette and measuring flask, and data processing, respectively, had a correct answer score percentage of 64%, 50%, 71%; and 91%. Then, in the acid-base titration experiment with the indicator tool selection, tool installation, tool function, observing the meniscus and the change in color of the endpoint titration, and data processing, respectively, have a correct answer score percentage of 84%, 100%, 73%; 80%; and 42%.

Keywords: Acid-base titration; Basic laboratory understanding; Dilution; Pictorial-based instrument; Standard solution

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1. INTRODUCTION

Education in higher education bridges societal needs, industrial needs, professional needs, and national excellence (Asmaningrum et al., 2018). The preparation of human resource qualification standards is manifested in Skill Competency Standards, which reflect the competencies a prospective teacher must possess. Apart from that, these standards must have equivalence and equality with relevant standards that apply to the education sector in other countries and even apply internationally as benchmarks (Eliyart & Rahayu, 2021). Improving the quality of human resources through educational pathways, from primary and secondary education to higher education, is the key to keeping up with global developments (Eliyart & Rahayu, 2021; Putri et al., 2020).

Science is a subject that requires complex abilities in all things, because in science, we do not only master knowledge through memorizing concepts, but must use analytical, critical and selective abilities in recognizing and solving problems that exist in learning (Sanchez, 2022). Prospective teachers are required to be able to educate students using a scientific approach so that all components of the material can be understood and well received by each student. This reason is used as the basis for providing more training and knowledge to carry out practical activities based on scientific skills (Hale-Hanes, 2015; Pujiastutik, 2018).

The science laboratory is a place that supports increasing students' knowledge and learning experiences in understanding science material. A science laboratory in a school is very helpful in successfully achieving learning objectives in science (Hayatun & Abu, 2017; Nuvitalia et al., 2021). However, because the ability to use the laboratory still needs to improve, this can result in less learning achievement. The quality of the learning process can determine learning success. Apart from the availability of good infrastructure, such as a science laboratory, there is a possibility that a teacher is also a factor in learning success. The problems faced and experienced by teachers in organizing laboratory activities are lack of practical equipment, lack of teacher knowledge and skills in managing laboratory activities, practical activities or laboratory activities are rarely carried out and take up a lot of time, teachers less able to plan experiments, formulate objectives, create student worksheets, manage and assess practicums so that they do not inspire students' thinking processes (Dwikoranto & Widiasih, 2023; Harefa & Fransisca Dewi Silalahi, 2020; Hayatun & Abu, 2017).

Practical activities are an inseparable part of science learning. Practicum is an integral part of science learning. The underlying reason why biology, physics, and chemistry are called experimental sciences. The teaching and learning process with practicum will allow students to experience for themselves, follow a process, observe an object, analyze, prove, and draw conclusions about a particular thing, situation, or process (Smith & Alonso, 2020). Therefore, one of the skills that prospective science teachers must master is the skill of designing practical activities. Knowing what basic laboratory skills students have before learning begins is essential to design knowledge related to laboratory activities. In this way, learning can focus on developing skills in lacking areas. Despite the extensive literature on learning in the laboratory, there are few studies on the laboratory skills students possess (Mistry & Shahid, 2021).

One way that can be done to develop students' basic laboratory skill is by applying several learning approaches or models, developing teaching materials, and developing questions and instruments (Karataş, 2016; Wei et al., 2018). Laboratory literacy is part of scientific literacy. Learning chemistry is based on understanding concepts and requires laboratory skills to test the truth of theories and discover the benefits of learning chemistry in everyday life. Based on this, basic laboratory skills are needed, including students' ability to understand various types of tools and their uses, recognize materials and their benefits, and safety in the laboratory.

Assessment is a way to determine a person's success in achieving a goal through performance. Assessment consists of two components, namely, collecting information about a person's performance and making a conclusive assessment based on the information that has been collected

(Pujiastutik, 2018). To determine a student's achievement, students are given several tasks in predetermined circumstances in such a way as to determine the student's abilities through various tasks in different situations and conditions. Assessment is needed to measure what a person can do and the extent to which a person's performance has improved after taking lessons (Eliyart & Rahayu, 2021).

One of the functions of assessment is to determine whether someone has mastered specific skills or knowledge. In this case, skills or knowledge are essential for a job. This type of assessment is called mastery assessment, an important part of competency-based training (Fitriah & Maknun, 2019). The assessment aims to gather sufficient evidence that the individual can perform or behave according to the standards set in a particular role. Another form of assessment is measuring ability levels. Ability assessment makes it possible to determine whether a person has mastered something he or she has learned. Assessment is intended to gather sufficient evidence to show that a person can exercise or behave according to specific standards in a particular role (Accettone et al., 2023).

Many of the current issues in chemistry laboratory education lie in the methods used to assess and evaluate students' abilities in the laboratory (Accettone et al., 2023; Karataş, 2016; Seery et al., 2017). The most common method for evaluating student achievement of desired learning outcomes in the laboratory is through the completion of a written laboratory report (Ong, 2018; Subali & Ellianawati, 2010). Although laboratory reports can investigate a student's understanding of the theoretical concepts introduced in the laboratory, they do not provide a means of evaluating the development of a student's practical laboratory understanding. One way to identify students' understanding in carrying out experiments is by using instruments equipped with pictures to provide an overview of the activities carried out in the practicum (Accettone et al., 2023). This method can be done through tests, so it only requires a short time compared to the observation process.

Many institutions have implemented laboratory skills training as a methodological teaching approach to equip educators with the ability to assess and refine students' laboratory skills (Hancock & Hollamby, 2020; Stephenson et al., 2020). These studies form the basis of this research to contribute to describe students' basic laboratory understanding. Based on this, this research aims to analyze the basic laboratory understanding of science students using pictorial-based instruments. Furthermore, educational and training institutions can use the findings of this research to prepare curricula that suit the needs of relevant laboratory skills.

2. METHODS

This research method uses quantitative descriptive research to provide an overview of the results of the analysis of basic laboratory knowledge of science education students using pictorial-based instruments—quantitative descriptive research. Quantitative descriptive research is a method used in the fields of social sciences, psychology, and other disciplines to regularly collect, analyze, and interpret numerical data to describe the characteristics of a population or phenomenon. This approach focuses on objective measurements, statistical analysis, and numerical representations to summarize and present information about a specific topic (Creswell, 2014). The sample in this study involved 43 science education students who had taken the practical course on chemical compound analysis. The sampling technique used simple random sampling (Tegeh et al., 2021) from the 2nd year student population. Data collection techniques are carried out through tests integrated into Google Forms. The data obtained was student answers, then analyzed quantitatively to calculate each experiment's average student understanding in basic laboratory understanding.

The instrument used was a pictorial-based instrument integrated into Google Forms. The basic laboratory understanding of science students focuses on understanding the preparation of standard solutions from solids, standard solutions from parent solutions, and acid-base titration experiments. Experiments on making solutions from solids focused on aspects of tool selection, tools function (weighing, taking solids, dissolving solids, and marking solution boundaries), observing the meniscus in a measuring flask, and data processing (calculations determining the solids to be weighed).

Experiments on making solutions from stock solution (dilution) focused on aspects of tool selection, tools function (taking stock solution, dilution, and marking solution boundaries), observing the meniscus in goiter pipettes and measuring flasks, and data processing (calculations determining the volume of stock solution taken). Then, the acid-base titration experiment focuses on aspects of tool selection, tools installation, tools function (taking the titrate, taking the titrant, titration process), observing (meniscus on the goiter pipette and measuring flask, and color changes at the end point of the titration), and data processing (the calculation determines the level of acetic acid in food vinegar) (Accettone et al., 2023; Enawaty, 2020; Juvitasari et al., 2018). The analysis is carried out on student responses based on correct and incorrect criteria based on images and reasons for choosing the answer. Then, the average percentage of correct answers for each indicator in each trial is calculated. The average percentage score of correct answers is the basis for describing students' basic laboratory understanding, which is supported by an explanation of the reasons for the student's answers.

3. RESULT AND DISCUSSION

The data obtained was in the form of student responses. The data analysis was carried out to describe the basic laboratory understanding of science education students in experiments on making solutions from solids, making solutions from stock solution (dilution), and acid-base titration (determining the level of acetic acid in food vinegar). Experiments on making solutions from solids focused on aspects of tool selection, tools function (weighing, taking solids, dissolving solids, and marking solution boundaries), observing the meniscus in a measuring flask, and data processing (calculations determining the solids to be weighed). Experiments on making solutions from stock solution (dilution) focused on aspects of tool selection, tools function (taking stock solution, dilution, and marking solution boundaries), observing the meniscus in goiter pipettes and measuring flasks, and data processing (calculations determining the volume of stock solution taken). Then, the acid-base titration experiment focuses on aspects of tool selection, tools installation, tools function (taking the titrate, taking the titrant, titration process), observing (meniscus on the goiter pipette and measuring flask, and color changes at the end point of the titration), and data processing (the calculation determines the level of acetic acid in food vinegar).

The experiment in making standard solutions from solids is spread over ten questions consisting of aspects of tool selection, tool function (weighing, taking solids, dissolving solids, and marking solution boundaries), observing the meniscus in a measuring flask, and data processing (calculations determining the solids to be weighed). The analysis results for each aspect are shown in Figure 1 below.

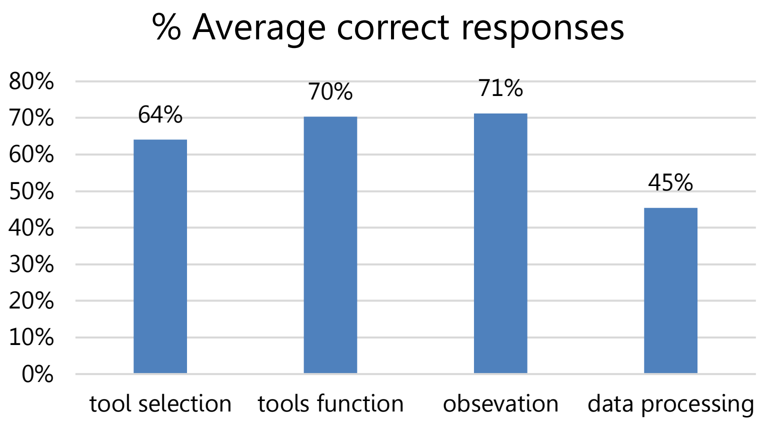

Figure 1. Students' response in the experiment of making standard solutions from solids

Based on Figure 1, students' knowledge of making standard solutions from solids in the data processing indicator has the lowest percentage, with an average correct answer response of 45%. This shows that less than half of the student's ability to analyze data for calculating the mass of solids that need to be weighed still needs to be higher. When calculating the mass of the solid being weighed, students need to use the formula for calculating the molarity of the solution with the equation:

$$M = \frac{n}{V} = \frac{mol}{Volume\ (L)}$$

Incorrect mathematical calculation operations cause errors that occur in this indicator. Many students still need help with the process of dividing and multiplying numbers. This shows the importance of numeracy literacy skills in this indicator. Students with good numeracy literacy skills can carry out mass calculation analysis of weighed solids. On the other hand, the indicator for making standard solutions from solids has the highest percentage of responses, namely when observing the solution meniscus, as much as 71%. Most students can observe the meniscus correctly. Namely, the eye position is parallel to the meniscus, and the concave line of the meniscus is in the position of the lower meniscus (Chang & Overby, 2011; Whitten et al., 2004), as shown in Figure 2.

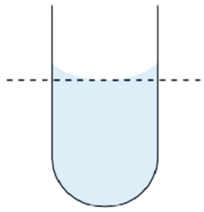

Figure 2. Lower meniscus

The experiment in making a standard solution from the stock solution (dilution) is spread over ten questions consisting of aspects of tool selection, tool function (taking the stock solution, dilution process, and marking the solution boundaries), observing the meniscus in the goiter pipette and measuring flask, and data processing (calculations). Determine the volume of stock solution taken). The analysis results for each aspect are shown in Figure 3 below.

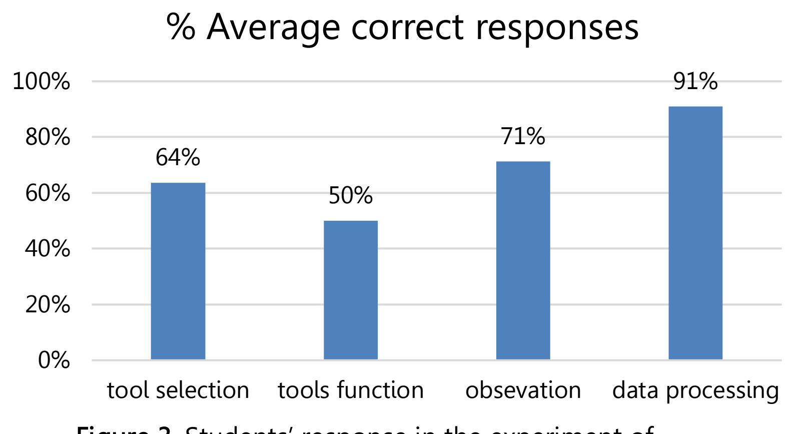

Figure 3. Students' response in the experiment of making standard solutions from stock solutions

Based on Figure 3, students' knowledge in making standard solutions from stock solution (dilution) on the tool function indicator has the lowest percentage, with an average correct answer response of 50%. This shows that half of the students still needed to be corrected in determining the function of the tool in the experiment. The function of the tool in question is to take the leading solution using a pipette/measuring pipette, the dilution process using a measuring flask, and mark the solution limit using a dropping pipette when it approaches the limit mark. The student responses that still showed errors were in taking the stock solution, where most students still chose to use a measuring cup. Taking the stock solution when making a standard solution uses a measuring pipette, which has a higher level of accuracy than a measuring glass (Hendrawan et al., 2021; Juvitasari et al., 2018). This is important to pay attention to because this experiment is a quantitative experiment in making a standard solution to be used as material for subsequent quantitative analysis. The highest number of correct responses was in the data processing indicator, 91%. This shows that most students can calculate the volume of stock solution taken using a measuring pipette. The calculations carried out have a more straightforward dilution calculation operation than calculations in experiments on making standard solutions from solids. The dilution calculation uses the following equation:

$$M_1 \times V_1 = M_2 \times V_2$$

Where M_1 is the concentration before dilution, V_1 is the volume of solution before dilution, M_2 is the concentration after dilution, and V_2 is the volume of solution after dilution.

The final experiment was an acid-base titration, which was spread over ten questions consisting of aspects of tool selection, tool installation, tool function (taking the titrate, taking the titrant, the titration process), observing (the meniscus on the goiter pipette and measuring flask, and the change in color of the endpoint titration), and data processing (calculations to determine the level of acetic acid in food vinegar). The analysis results for each aspect are shown in Figure 4 below.

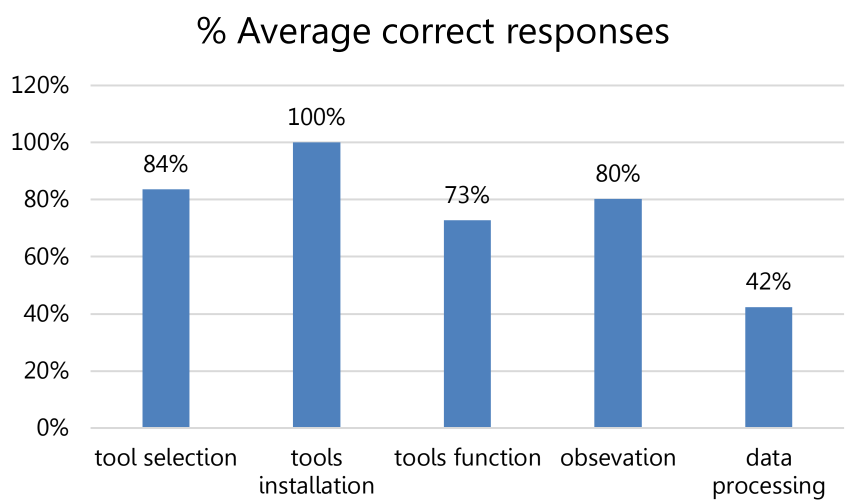

Figure 4. Students' response in the experiment of acid-base titration

Based on Figure 4, students' basic laboratory knowledge in acid-base titration experiments has the lowest percentage of correct answers in the data processing indicator, with a response of 42%. This shows that less than half of the student's ability to analyze data to calculate acetic acid levels in food vinegar still needs to be higher. When calculating the concentration of acetic acid through the titration process, students need to use the following equation:

$$M_a \times V_a = M_b \times V_b$$

Where Ma is the concentration of acid, Va is the volume of acid, Mb is the concentration of base, and Vb is the volume of base.

Then, students used the dilution factor to calculate the concentration of acetic acid in the food vinegar sample. This is because the titrated vinegar sample was a 5 mL vinegar sample, which was then added to 15 mL of distilled water to make 20 mL. So, the solution being titrated is a sample solution diluted with distilled water. Most students skip this step and assume that the acetic acid concentration resulting from the titration is the concentration of acetic acid in food vinegar. So, the results of calculating acetic acid levels in food vinegar samples must be corrected. Furthermore, the correct answer with the most significant percentage in the acid-base titration experiment was 100% for the instrument installation indicator. This shows that all students can correctly assemble a set of acid-base titration experiment tools. The correct design of the titration tool set is to install the burette perpendicularly on the stand and clamp. Then, there is an Erlenmeyer flask, which is placed under the burette faucet (Enawaty, 2020; Shintya Dewi et al., 2019). The correct installation of the toolset is shown in Figure 5.

Figure 5. Titration tool set

4. CONCLUSION

Based on the analysis carried out, it can be concluded that analysis of basic laboratory understanding of science education students using pictorial-based instruments in the experiment of making standard solutions from solids with indicators tool selection, tool function; observing the meniscus in a measuring flask; and data processing respectively have a correct answer score percentage of 64%; 70%; 71%; and 45%. The experiment in making standard solutions from the stock solution (dilution) with indicators tool selection, tool function, observing the meniscus in the goiter pipette and measuring flask, and data processing, respectively, have a correct answer score percentage of 64%, 50%, 71%; and 91%. Then, in the acid-base titration experiment with the indicator tool selection, tool installation, tool function, observing the meniscus and the change in color of the endpoint titration, and data processing, respectively, have a correct answer score percentage of 84%, 100%, 73%; 80%; and 42%. This shows that students have a good basic laboratory understanding from the three experiments based on the percentage of correct answer scores in each indicator. Almost all of them have scores above 50%.

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