UNESA Journal of Chemical Education *ISSN: 2252-9454*
Vol. 15, No. 2, pp. 172–178, May 2026

IMPLEMENTATION OF MASS COMPARISON PRACTICUM TO REDUCE MISCONCEPTION ON LAVOISIER'S LAW AT SMAN 11 SURABAYA

Fany Aulia Nur Fadhilah[1]*, Kusumawati Dwiningsih[1], and Bambang Purwantoro[2]

[1]Departement of Chemistry, FMNS, Universitas Negeri Surabaya

[2]SMAN 11 Surabaya

e-mail: fany.23056@mhs.unesa.ac.id

Abstract

This study aimed to identify students misconceptions regarding the law of conservation of mass and to examine the effectiveness of laboratory activities in reducing these misconceptions. The study employed a quantitative descriptive using a Pre-Experimental One Group Pretest-Posttest Design involving 33 students of class X-2 at SMAN 11 Surabaya. The study was conducted in one experimental class without a control group. The research instrument used was a three-tier diagnostic test consisting of the categories understanding, misconception, not understanding, and uncertainty. Data were collected through observation, documentation, pretest and posttest. Data analysis was conducted using the Shapiro-Wilk normality test, Wilcoxon signed-rank test, and N-gain calculation with the assistance of SPSS version 32. The results showed that the percentage of students experiencing misconceptions decreased from 82% in the pretest to 3% in the posttest, while the percentage of students in the understanding category increased from 15% to 97%. The Wilcoxon Signed-Rank Test showed a significance value of <0,001, indicating that H_0 was rejected and H_1 was accepted. In addition, the average N-gain score was 0,9294, which falls into the high category. These findings indicate that the implementation of a mass comparison laboratory activity was effective in reducing students misconceptions and improving their understanding of the law of conservation of mass through direct empirical learning experiences and conceptual reconstruction.
Keywords: practicum, misconception, Lavoisier's Law, three-tier diagnostic test, N-gain.

INTRODUCTION

The study of chemistry has distinct characteristics compared to other subjects, as it requires not only qualitative understanding but also quantitative skills. In chemistry, quantitative skills involve the relationships between mass, moles, volume, and the number of particles in a given chemical reaction. One of the fundamental concepts that serves as the foundation for understanding these quantitative relationships is the basic laws of chemistry, particularly the law of conservation of mass. Understanding the fundamental laws of chemistry is crucial before students study stoichiometry and other advanced chemistry topics such as thermochemistry, reaction rates, and chemical equilibrium [1].

The fundamental laws of chemistry consist of five key principles: the Law of Conservation of Mass (Lavoisier), the Law of Definite Proportions (Proust), the Law of Multiple Proportions (Dalton), the Law of Volumetric Proportions (Gay-Lussac), and Avogadro's Hypothesis [2]. Among these five laws, the Law of Conservation of Mass is a fundamental concept in stoichiometric analysis because it states that the mass of substances before and after a chemical reaction in a closed system remains unchanged. Stoichiometry itself is the study of the quantitative relationships between substances involved in chemical reactions, whether in terms of mass, moles, or volume [3]. Stoichiometric concepts are abstract and interrelated, thus requiring a solid conceptual understanding from students. However, in practice, stoichiometry is often taught using a mathematical approach, so students tend to focus more on calculation procedures than on understanding the concept [4].

 ISSN: 2252-9454

Difficulty in understanding basic chemistry concepts can lead to ideas that are inconsistent with scientific principles agreed upon by experts. Such discrepancies are referred to as misconceptions [5]. Several studies indicate that the fundamental laws of chemistry are among the topics students find difficult due to their abstract and mathematical nature [6]. In line with these theoretical studies, a number of empirical studies show that the subjects of basic chemical laws and stoichiometry remain sources of difficulty in learning. Based on observations from [7] it was found that students understanding of reaction equations and limiting reactants was still inadequate. Research of [8] noted that the rate of misconceptions in stoichiometry material reached 44,6%, while [9] also found misconceptions regarding the law of conservation of mass at 23%. Additionally, an average of 33,4% of students still make errors when solving problems. These research findings indicate that instruction on fundamental chemical laws still tends to be focused on mathematical problem-solving without being balanced by empirical experiences that allow students to verify concepts directly.

One learning method that can be used to reduce misconceptions is an empirical verification-based laboratory activity. Laboratory work provides students with the opportunity to observe chemical phenomena firsthand, making the concepts they learn more tangible. In this study, a laboratory activity was conducted to analyze the mass of a system before and after the reaction producing CO_2 gas in a closed system, to observe the application of the law of conservation of mass empirically. The gas formation reaction was chosen because this type of reaction often leads to misconceptions, particularly the belief that the mass of a substance decreases when the gas produced by the reaction escapes from an open system. Through this laboratory activity, students compare the total mass of the system before and after the reaction and analyze the measurement results based on the concept of the law of conservation of mass. This activity is expected to help students understand the relationship between theory and experimental results directly. In addition to deepening their understanding of the concepts, the laboratory activity also serves to develop students quantitative analysis skills, precision in measurement, and the cultivation of a scientific attitude.

Based on the above description, this study aims to identify the impact of implementing a laboratory experiment on the comparative analysis of system mass before and after the CO_2 gas formation reaction on reducing students misconceptions regarding the law of conservation of mass at SMAN 11 Surabaya.

METHODS

This study is a quantitative study using a pre-experimental one-group pretest-posttest design, involving only one experimental class without a control class. The study aims to reveal the impact of implementing a laboratory experiment on the analysis of mass conservation before and after the CO_2 gas formation reaction on reducing misconceptions regarding the law of conservation of mass among 10th-grade students at SMAN 11 Surabaya.

Data were collected through pretest and posttest using a three-tier diagnostic test instrument, supported by observation and documentation. Initial observation was conducted to identify learning issues and the level of students' misconceptions regarding the law of conservation of mass. Documentation was used to record learning activities and the implementation of the laboratory practice.

The instrument used was a three-tier diagnostic test to identify students' level of understanding before and after the laboratory practice. This instrument consists of three levels: multiple-choice questions, justifications for answers, and students' confidence levels regarding their chosen answers. Based on the combination of these three levels, students' understanding levels were categorized into concept mastery, misconceptions, does not understand the concept, and not confident. The categories of the three-tier diagnostic test are presented in Table 1.

Table 1. Categories of the Three-Tier Diagnostic Test

Student Response Patterns	Result
Correct answer, correct reasoning, and confident	Understands
Incorrect answer or reasoning but confident	Misconception
Incorrect answer and not confident	Does not understand the concept
Correct answer but not confident	Not confident

This laboratory activity involved comparing the mass of the system before and after a reaction that produced CO_2 gas in a closed system. During the activity, students measured mass, observed the reaction, and analyzed experimental data to empirically verify the law of conservation of mass.

Data analysis was performed using quantitative statistical methods with SPSS version 32. Prior to testing the hypothesis, a normality test was conducted using the Shapiro–Wilk test because the sample was less than 50. The results showed that the posttest data were not normally distributed, the Wilcoxon Signed-Rank test was used to determine the difference between students' pretest and posttest results. Additionally, an analysis of the improvement in students' understanding was conducted using N-Gain calculations to measure the effectiveness of the laboratory activity in reducing students' misconceptions regarding the law of conservation of mass.

RESULTS AND DISCUSSION

This study aims to determine the effect of conducting a laboratory experiment on the mass analysis of a system before and after the CO_2 gas formation reaction on reducing students misconceptions regarding the law of conservation of mass at SMAN 11 Surabaya. This experiment was conducted by inducing a reaction between vinegar (CH_3COOH) and baking soda ($NaHCO_3$) in a closed system, using a balloon to collect the gas produced by the reaction.

Before the laboratory experiment was conducted, students were given a pretest using a three-tier diagnostic test to measure their initial level of understanding of the concept of the law of conservation of mass. The pretest results are shown in Table 2.

Table 2. Pretest Results

Category	Result
Understand	15%
Misconception	82%
Unsure	3%

Table 2 shows that the "misconception" category had the highest percentage compared to the other categories. These findings indicate that many students still experienced misconceptions regarding the law of conservation of mass. Most students assumed that gas does not have mass because it cannot be directly seen after the reaction occurs. In addition students also did not fully understand the concept of a closed system, causing them to believe that the total mass of substance decreases when gas is produced during a chemical reaction. These misconceptions were identified particularly in questions related to gas-forming reactions and the comparison of system mass before and after reaction. Students tended to assume that the CO_2 gas produced during the reaction disappeared into the air and no longer contributed to the total mass of the system.

After the learning process through a laboratory experiment analyzing the mass of the system before and after the CO_2 gas formation reaction, students were given a posttest using the same instrument to determine changes in their level of understanding. The posttest results are presented in Table 3.

Table 3. Posttest Result

Category	Result
Understand	97%
Misconception	3%
Unsure	0%

Based on Table 3, there was an increase in the percentage of students in the "understand" category and a decrease in the percentage of students with misconceptions after the laboratory experiment. These results indicate that laboratory-based learning helps students better understand the concept of the law of conservation of mass through direct empirical evidence.

 ISSN: 2252-9454

Through the laboratory practicum, students directly observed that the balloon expanded as a result of CO_2 gas formation, indicating that the gas produced during the reaction remained inside the closed system. This observation helped students understand that gas still has mass even though it cannot be seen directly. In addition the use of a closed system enabled students to observe that the total mass of the system before and after the reaction remained relatively constant. This empirical experience helped students reconstruct their understanding of the law of conservation of mass and reduced misconceptions identified during the pretest. The decrease in the percentage of misconceptions and the increase in students conceptual understanding in the posttest indicate that the laboratory practicum was effective in helping students connect theoretical concepts with direct experimental observation.

In this study, a laboratory experiment comparing the mass of a system before and after a CO_2 gas formation reaction was conducted with students in class X-2 at SMAN 11 Surabaya. During the experiment, students were divided into several groups, and each group was provided with materials and equipment—including vinegar, baking soda, a balloon, a Erlenmeyer flask, and a digital scale to conduct the law of conservation of mass experiment. The first step was to weigh 5 grams of baking soda and place it inside a balloon, then pour 50 mL of vinegar into the Erlenmeyer flask. Once everything was ready, the balloon was carefully attached to the mouth of the Erlenmeyer flask to ensure the system remained sealed and the baking soda did not mix with the vinegar. The initial mass of the system before the reaction was then measured using a digital scale, and the results were recorded. The next step is for the students to pour the baking soda from the balloon into the Erlenmeyer flask containing the vinegar. When the two substances mix, a chemical reaction occurs that produces carbon dioxide (CO_2) gas, causing the balloon to expand. After the reaction is complete, the students weigh the final mass of the system again and compare the result with the mass before the reaction to analyze it based on the concept of the law of conservation of mass. Throughout the lab activity, the students appeared active and enthusiastic. The implementation of this lab received a positive response from the students because learning was conducted directly through experimental activities rather than solely through theoretical explanations and mathematical calculations.

In the lab activity, students measured the system's mass before and after the reaction occurred. The reaction took place in a closed system, so the carbon dioxide (CO_2) gas produced remained inside the system and caused the balloon to expand. Through this activity, students observed that the mass of the system before and after the reaction did not undergo a significant change when the reaction occurred in a closed system. Students could directly observe that the total mass of the system before and after the reaction tended to remain constant, consistent with the law of conservation of mass proposed by Antoine Lavoisier.

The results of this study are in accordance with the theory of constructivism that has been described in the initial section. Constructivism emphasizes that learning is an active process in which students build their own knowledge through exploration and experience. In the practicum activity, students directly observed the development of balloons due to the formation of carbon dioxide (CO_2) gas, while the total mass of the closed system remained quite stable. This observation provides empirical evidence that contradicts the student's initial misconception that gas has no mass. This event causes a cognitive conflict between the student's initial beliefs and the results of observations obtained during the practicum. This cognitive conflict motivates students to reconstruct their understanding so that their misconceptions can be replaced with proper scientific concepts regarding the Law of Conservation of Mass. Thus, practicum not only serves as a conceptual activity, but also as a meaningful learning experience that supports conceptual change and reduces misconceptions.

Nevertheless, some groups still obtained initial and final masses that were not entirely the same. These differences were influenced by several factors during the experiment, such as baking soda adhering to the balloon so that not all of the

ISSN: 2252-9454

substance reacted with the vinegar, a small leak in the balloon causing CO_2 gas to escape from the system, and the fact that the experiment was not conducted in a vacuum, leaving room for environmental influences on the mass measurement process. However, these conditions actually help students understand that discrepancies in lab results can be influenced by experimental errors and imperfect system conditions.

Before testing the hypothesis, the normality of the pretest and posttest data was first tested using the Shapiro-Wilk test, since the sample size was less than 50 students. The results of the Shapiro-Wilk test are presented in Table 4.

Table 4. Shapiro-Wilk Test Result

Data	Sig	Notes
Pretest	0,057	Normally distributed
Posttest	<0,001	Not normally distributed

Based on Table 4, it is evident that the pretest data has a significance value of 0,057 (>0.05) and is therefore normally distributed, whereas the posttest data has a significance value of <0.001 (<0,05) and is therefore not normally distributed. Since one of the datasets is not normally distributed, the hypothesis test was conducted using the Wilcoxon Signed-Rank Test. The hypotheses used in this study are as follows.

H_0: The implementation of a laboratory experiment comparing the mass of a system before and after the CO_2 gas formation reaction has no effect on reducing misconceptions regarding the law of conservation of mass.

H_1: There is an effect of the implementation of the laboratory experiment analyzing the mass ratio of the system before and after the CO_2 gas formation reaction on the reduction of misconceptions regarding the law of conservation of mass.

The results of the Wilcoxon hypothesis test are presented in Table 5.

Table 5. Results of the Wilcoxon Signed-Rank Test

Statistical Test	Sig.^{a,b}	Decision
Wilcoxon Signed Rank Test	<0,001	H_0 rejected

Based on Table 5, the results of the Wilcoxon Signed-Rank Test indicate a significance level of <0,001 (<0,05), so H_0 is rejected and H_1 is accepted. These results show that the implementation of a laboratory experiment comparing the mass of a system before and after a CO_2 gas formation reaction has an effect on reducing students misconceptions regarding the law of conservation of mass at SMAN 11 Surabaya.

Next, an N-gain score test was conducted to measure the effectiveness of the laboratory activity in reducing students misconceptions regarding the law of conservation of mass. The N-gain calculation used [10] formula as follows.

N-gain (g) = $\frac{X_2 - X_1}{X_{max} - X_1}$

Notes :

X_1 = pretest score

X_2 = posttest score

X_{maks} = maximum score

The categorization of N-gain scores to measure the effectiveness of the laboratory experiment in reducing students misconceptions regarding the law of conservation of mass is presented in Table 6.

Table 6. N-Gain Score Categories

N-gain score	Category
$g > 0,7$	High
$0,3 \leq g \leq 0,7$	Currently
$g < 0,3$	Low

[10]

Based on the calculation results, the average N-gain score was 0,9294, which falls into the high category. These results indicate that the implementation of the laboratory experiment comparing the mass of the system before and after the CO_2 gas formation reaction is effective in enhancing students understanding and reducing misconceptions regarding the law of conservation of mass. This laboratory activity provides students with direct experience in observing mass changes before and after the reaction occurs, thereby making the concept of the law of conservation of mass which was initially abstract more tangible and easier to understand.

Before the experiment many students held misconceptions, particularly the belief that the mass of a substance decreases when a reaction produces gas. After the experiment, students realized that the gas produced by the reaction retains its mass and remains measurable if the reaction occurs in a closed system; this understanding was gained through direct observations of the balloon expanding due to the formation of carbon dioxide (CO_2) gas without significantly altering the total mass of the system. Although some groups obtained initial and final mass results that were not entirely the same, the activity still helped students understand that differences in experimental results can be influenced by various factors during the laboratory session. These factors include baking soda powder adhering to the balloon, preventing all of it from reacting with the vinegar; leaks or small holes in the balloon allowing carbon dioxide (CO_2) to escape from the system; and the fact that the experiment was not conducted in a vacuum, leaving room for environmental influences on the mass measurement process.

By analyzing the results of the laboratory practicum, students were able to understand that the law of conservation of mass or Lavoisier's law still applies when a reaction occurs in a closed system. Through direct observation, students realized that the CO_2 gas produced during the reaction remained inside the system and continued to contribute to the total mass, even though the gas could not be seen directly. This finding helped students correct their misconceptions that gas has no mass and that the total mass decreases when gas is produced during a chemical reaction.

In addition to improving conceptual understanding, the laboratory practicum also helped students develop analytical skills, accuracy in conducting experimental evidence. The significant decrease in misconceptions and the increase in students understanding in the posttest indicate that laboratory-based learning was effective in helping students understand the law of conservation of mass more meaningfully.

CONCLUSION

The results of this study indicate that the implementation of a laboratory experiment comparing the mass of a system before and after a CO_2 formation reaction significantly reduced students misconceptions regarding the law of conservation of mass at SMAN 11 Surabaya. The pretest results showed that many students still held misconceptions, particularly regarding the assumption that gas has no mass and the misunderstanding of closed system reactions. After participating in the laboratory practicum, students demonstrated improved conceptual understanding in the posttest results. The results of the Wilcoxon Signed-Rank Test showed a significance value of <0,001 ($p < 0{,}05$), indicating a significant difference between students pretest and posttest scores. In addition the N-gain calculation results showed an average of 0,9294 in the high category, indicating that the laboratory practicum is effective in helping students understand the concept of the law of conservation of mass and reduce misconceptions through direct learning experiences. The laboratory activity enabled students to directly observe that the CO_2 gas produced during the reaction remained inside the closed system and continued to contribute to the total mass of the system. This empirical observation created cognitive conflict with students initial misconceptions and encouraged conceptual reconstruction, allowing students to develop a more scientifically accurate understanding of the law of conservation of mass. In addition to improving conceptual understanding, the laboratory activity also helped students develop analytical skills, precision in measurement, and scientific thinking skills throughout the chemistry learning process.

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