Multiple representation-based chemistry learning textbook of colloid topic

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Abstract. This study aimed to describe the differences in students' learning outcomes using the multiple representation-based chemistry learning textbook and the conventional chemistry learning textbook. This study was a quasi-experimental research. The population of this study was eight classes of Mathematics and Natural Sciences at SMAN 4 Denpasar Bali Indonesia. The samples were selected by cluster sampling technique to determine a control and an experimental group. Students in the control group were taught by the conventional chemistry learning textbook, while students in the experimental group were taught by the multiple representation-based chemistry learning textbook. The data in the study were students' learning outcomes. These data were analyzed using the analysis of covariance statistics. Results of the study showed that there was a significant difference in learning outcomes between students taught by the multiple representation-based chemistry learning textbook and those taught by the conventional chemistry learning textbook. From the mean of learning outcome scores, it could be concluded that the students' learning outcomes who were taught by the multiple representation-based chemistry learning textbook were better than those of the conventional chemistry learning textbook.

1. Introduction
Chemistry discusses the properties of matter, the structure of matter, the changes of matter, and the accompanying energy. Not only discuss phenomena at the macroscopic level but also discuss them at the sub-macroscopic and symbols level [1]. Chemistry concepts at the macroscopic level are concepts related to real phenomena. The concepts at the sub-macroscopic level are concepts that explain macroscopic phenomena (related to the information about atoms, molecules, and kinetic aspects of substances). Finally, the concepts at the symbolic level are concepts related to the use of symbols, diagrams, and formulas [2]. Understanding chemistry deeply can be achieved if students can think using internal representations that have been built through the three representations, namely macroscopic, sub-macroscopic, and symbolic level [3–5].

However, the representation of chemistry, particularly in the sub-macroscopic and symbolic levels, causes students to experience difficulties in understanding chemistry concepts. This is due to the sub-macroscopic and symbolic levels were abstract concepts. Both of these levels will make chemistry less attractive to students because students cannot imagine the concept of chemistry at the particular or sub-macroscopic level [2, 6]. Helping students to understand chemistry well can be done by displaying various representations. The representations were a visual, written, or audio form of something, living things or processes that have meaning to be conveyed [7]. They can be divided into two, namely internal representations and external representations [8]. The internal representations were the mental
constructions of a person or what is known as a mental image. The external representations were a way of physically showing concepts or ideas. They can be in the form of image words, animations, videos, symbols, calculations, diagrams, or graphs [9].

The use of various representations (macroscopic, sub-microscopic, and symbolic) in one chemical concept is called multiple representations [10]. The multiple representations can help display phenomena that are not possible to be seen or felt directly by students [11], so that the phenomena can be easily understood. The use of correct multiple representations not only can improve students' conceptual understanding of chemistry but also can enhance teachers' understanding of students' abilities in interpreting and using the various chemical representations [12]. Besides, students can build mental models of phenomena and can explain the relationships between the three levels of representation [13].

There are three main functions of multiple representations [14]. The three functions are as follows: (1) complementary roles, different representations will certainly provide different information so that by understanding various representations, students can find out a lot of information; (2) constrain interpretation, external multiple representations often help students when the first representation impedes the following representation; (3) construct deeper understanding, by understanding various representations, students can connect one representation with other representations so that students can understand more complex concepts.

The use of multiple representations must be part of learning materials, textbooks, and media so that they can bridge all three levels of chemistry concepts [15]. Therefore, the use of textbooks or appropriate learning methods can be one of the solutions of learning problems. This is caused by students' mental models derived from books or students' interactions in the learning process. [3]. Based on this, it is important to investigate the effect of using the multiple representation-based chemistry learning textbook on students’ learning outcomes compared to the conventional chemistry textbook. Thus, the goal of this study was to compare the effectiveness of the multiple representation-based chemistry learning textbook and the conventional chemistry textbook on students’ learning outcomes, especially on colloid topics.

2. Method

2.1 Type of Research
To determine the effect of the multiple representation-based chemistry learning textbook on students' learning outcomes, a quasi-experimental study with the non-equivalent pretest-posttest control group design was conducted. The conventional chemistry learning textbook was used as controls. It was the textbook that was usually used by teachers in schools. This study was carried out on the topic of colloids.

2.2 Population and Sample
The population of the study was the eleventh-grade students of SMAN 4 Denpasar, Bali, Indonesia, which consists of eight classes majoring in Mathematics and Natural Sciences. Samples were taken by a cluster sampling technique. The number of samples taken was two classes. Both classes were drawn to get a control group and an experimental group. The control and experiment groups were 36 and 35 students, respectively.

2.3 Data Collection
The stages of learning carried out in the two groups were the same, namely a scientific approach which includes the phases of observing, asking questions, collecting data, associating, and communicating. At the observing phase, students were given a description of several paragraphs about colloids, then at the questioning phase, students were given time to ask questions that arose in their minds after reading the paragraph. Questions were accommodated and recorded by all students. Furthermore, at the data collecting phase, students collected data to be able to answer questions that had been formulated previously. Discussions of the questions were done through small group discussions (4-5 people). In the
associating phase, students were given follow-up questions that had been prepared on the students’ worksheets. Finally, at the communicating phase, students presented their work in front of the class.

The differences in the treatment given to the control and experimental groups were the sources of learning. In the control group, students used sources in the form of the conventional chemistry learning textbook, whereas in the experimental group students used sources in the form of the multiple-based chemistry learning textbook. Research data were collected using a learning outcome test, especially on the cognitive dimension. The test was carried out twice, namely before treatment (pretest) and after treatment (posttest). Pretest and posttest were done using the same test for both groups.

2.4 Learning Devices and Research Instruments

To help the learning processes in this study, the multiple representation-based chemistry learning textbook, the syllabus, learning implementation plan, and students’ worksheets were used. One model of multiple representations contained in the textbook was shown in Figure 1. Colloid subtopics that can be presented using multiple representations included (a) particle sizes of colloid, (b) types of colloid, (c) properties of colloid, and manufacture of colloid.

On the other hand, a test was used to collect data of students' learning outcomes, especially on the cognitive dimension. Indicators of competency achievement of the test include (a) determining differences of solutions, suspensions, and colloids, (b) distinguishing dispersing and dispersed phases, (c) classifying types of colloids, (d) explaining the properties of colloids, (d) explaining the use of colloids in everyday life, and (e) making colloidal products involving the principles of colloids. The test was an objective test (15 items) and an essay (3 items). Before being used, the test has been tested for validity, reliability, level of difficulty, and different power. Test results showed that the validity of objective and essay tests were 0.43-0.82 and 0.51-0.84, respectively; the reliability of the objective and essay tests were 0.73 and 0.94 respectively; the level of difficulties of the objective and essay test were 0.53-0.91 and 0.13-0.46, respectively; and the discriminating power of the objective and essay test were 0.25-1.00 and 0.69-0.83, respectively.

![Figure 1. Multiple representation models: (a) sugar solution, (b) colloid of milk, (c) suspension (water and sand mixtures), and (d) sucrose structure](image-url)
2.5 Data Analysis
The data of this study were data of learning outcomes. The data were analyzed using a statistical technique of analysis of covariance (Ancova). The hypothesis being tested was as follows.

$H_0$: There is no significant difference in learning outcomes between students taught by using the conventional chemistry learning textbook and students taught by using the multiple representation-based chemistry learning textbook.

$H_a$: There is a significant difference in learning outcomes between students taught by using the conventional chemistry learning textbook and students taught by using the multiple representation-based chemistry learning textbook.

Before the Ancova test was carried out, assumption tests needed to be carried out. These tests included the normality test, the variance homogeneity test, the linearity test, and the slope homogeneity test (interaction test). In this study, all tests were performed with the help of SPSS software Ver. 22 for Windows at a significance level of 5%.

3. Results and Discussion

3.1 Results
3.1.1. Pretest and posttest. The pretest and posttest were conducted in both groups (control and experiment) using the same test to obtain the learning outcome data. A summary of students’ learning outcome data was presented in Table 1.

| Statistics          | Pretest | Posttest |
|---------------------|---------|----------|
|                     | Control Group | Experimental Group | Control Group | Experimental Group |
| Mean                | 36.86   | 43.66    | 70.92        | 79.43           |
| Standard deviation  | 16.38   | 14.44    | 7.63         | 8.15            |

Next, the learning outcomes data were analyzed using Ancova. However, several assumptions tests had to be fulfilled first, namely tests of normality, homogeneity, linearity, and slope of the regression line. The assumption test results that have been carried out were as follows.

3.1.2. Normality test. The normality test was carried out using the Shapiro-Wilk technique. The results of the normality test were presented in Table 2. The results of this test indicated that all significance values were more than 0.05. It could be concluded that all learning outcomes data (pretest and posttest) had been normally distributed.

| Test        | Group             | Shapiro-Wilk |
|-------------|-------------------|--------------|
|             |                   | Statistic    | df | Sig.  |
| Pretest     | Control Group     | 0.965        | 36 | 0.301 |
|             | Experimental Group| 0.953        | 35 | 0.143 |
| Posttest    | Control Group     | 0.945        | 36 | 0.072 |
|             | Experimental Group| 0.956        | 35 | 0.174 |

3.1.3. Homogeneity variance test. The homogeneity test for the variance of the two groups was carried out using the Levene test. The results of this test indicated significance values were more than 0.05. This meant that the pretest and posttest score variances in both groups were homogeneous. The results of the variance homogeneity test were presented in Table 3.
Table 3. Homogeneity variance test results

| Test     | Description       | Levene Statistic | df1 | df2 | Sig.   |
|----------|-------------------|------------------|-----|-----|--------|
| Pretest  | Based on Mean     | 0.996            | 1   | 69  | 0.322  |
| Posttest | Based on Mean     | 0.112            | 1   | 69  | 0.739  |

3.1.4. Linearity test. The linearity test was conducted to determine the linear relationship between pretest and posttest scores in the control and experimental groups. The linearity test results could be seen in Table 4. The significance values in the linearity row for the control and experimental groups were less than 0.05. This means that there was a significant relationship between posttest and pretest scores both in the control group and in the experimental group. The significance values in the line of deviation of linearity for the control and experimental groups were more than 0.05. That is, the relationship between pretest and posttest scores was linear.

Table 4. Linearity test results

| Group            | Criteria                   | Sum of squares | df  | Mean square | F       | Sig.   |
|------------------|----------------------------|----------------|-----|-------------|---------|--------|
| Control Group    | Linearity                  | 3195.920       | 1   | 3195.920    | 15.075  | 0.001  |
|                  | Deviation from linearity   | 474.195        | 7   | 67.742      | 0.320   | 0.939  |
| Experimental Group | Linearity              | 1933.540       | 1   | 1933.540    | 9.639   | 0.006  |
|                  | Deviation from linearity   | 1686.377       | 14  | 120.455     | 0.600   | 0.834  |

3.1.5. The slope of the regression line test. This test was intended to determine whether there was an interaction between the treatment (chemistry learning textbooks) towards learning outcomes. The significance value in the line of "Treatment*pretest" was more than 0.05. It indicated that there was no interaction between the regression line of pretest and posttest scores in the control group with the regression line of pretest and posttest scores in the experimental group. This clarified that students' learning outcomes were only influenced by treatment or independent variables (chemistry learning textbooks), not by other variables. The results of the homogeneity test of the regression line slope were shown in Table 5.

Table 5. Results of the homogeneity test of regression line slope

| Sources             | Type III Sum of Squares | df  | Mean Square | F       | Sig.   |
|---------------------|-------------------------|-----|-------------|---------|--------|
| Treatment           | 103.989                 | 1   | 103.989     | 2.240   | 0.139  |
| Pretest             | 1160.592                | 1   | 1160.592    | 24.997  | 0.000  |
| Treatment*pretest   | 0.224                   | 1   | 0.224       | 0.005   | 0.945  |

3.1.6. Hypothesis test. Based on assumption tests that have been carried out, all data obtained met the requirements of tests of normality, homogeneity, linearity, and regression line slope. Thus, the Ancova test could be continued. The test results of Ancova statistics could be seen in Table 6. The significance value in the "treatment" row was less than 0.05. This meant that it was H₀ was rejected or H₀ was accepted.
Table 6. Results of the covariance analysis test

| Source   | Type III Sum of Squares | df | Mean Square |    F   | Sig,     |
|----------|-------------------------|----|-------------|--------|----------|
| Pretest  | 1188.377                | 1  | 1188.377    | 25.976 | 0.000    |
| Treatment| 755.973                 | 1  | 755.973     | 16.524 | 0.000    |

3.2 Discussion

Based on the results of hypothesis testing that had been done, it could be concluded that there was a significant difference in learning outcomes between students taught by using the conventional chemistry learning textbook and students taught by using the multiple representation-based chemistry learning textbook. The mean score of students taught by using the multiple representation-based chemistry learning textbook (79.43) was higher than that of students taught by using the conventional chemistry learning textbook (70.92).

In this study, the learning applied to both groups was a scientific approach. This approach was recommended for implementing Curriculum-13. Stages of learning with a scientific approach included the stages of observing, asking, gathering information, associating, and communicating. In the observing stage, students read colloidal contents related to daily life. Then, in the questioning stage, students asked questions related to information that they just read. Furthermore, students entered the stage of gathering information to be able to answer the questions that had been asked. In the associating stage, students processed information obtained to be able to answer further questions that had been prepared at the worksheet. The last step is communicating. At this stage, students presented and discussed the results of their work in front of the class.

Some of the benefits of learning with a scientific approach [16] include: (1) learning is student-centered, (2) students can build their knowledge concepts, (3) students can apply scientific stages, and (4) students can do social interaction through group discussions. Learning with a scientific approach is also the inquiry-based and cooperative learning. The former reason is that students conduct an independent investigation in finding answers to questions [17]. The latter reason is that students work in small groups then discuss them in larger groups so that each group is responsible for what is found [18].

The difference between the implementation of learning with a scientific approach in the control group and the experimental group is at the stage of collecting data or information. In the control group, students used the conventional chemistry learning textbook that was commonly used by chemistry teachers as learning sources. On the other hand, in the experimental group, students used the multiple representation-based chemistry learning textbook.

The use of the multiple representation-based chemistry learning textbook as a source of learning is very effective in improving the students’ learning outcomes. This is caused by the textbook displays three levels of chemistry concepts, namely macroscopic, sub-microscopic, and symbolic levels that are relevant to the characteristics of chemistry. The visualization of the three levels of these concepts can help students to understand chemical phenomena that are mostly related to the sub-microscopic level [19–22]. In addition, learning with multiple representations also optimizes the ability of students to imagine and interpret overall chemical phenomena [23].

All three levels of representations can also improve students' reasoning abilities [23, 24]. Students' understanding becomes more meaningful and is stored longer in the brain [12]. In addition, learning with multiple representations is also known to increase students' critical thinking [25], foster students' creative thinking skills [15], and reduce students' misconceptions [26]. The right learning strategy will be able to reduce students' misconceptions [27, 28]. Thus, students will get satisfaction [29].

4. Conclusion

Chemistry learning should pay attention to the interrelationship of three levels of chemistry, including macroscopic, sub-microscopic, and symbolic concepts (using multiple representations). The use of
multiple representations in chemistry learning can be done by integrating them into the chemistry learning textbook. The results showed that the pretest and posttest scores in the control group were 36.86 and 70.92, respectively. On the other hand, the pretest and posttest scores in the experimental group were 46.66 and 79.43, respectively. Furthermore, the results of statistical tests indicated that the multiple representation-based chemistry learning textbook is better than the conventional chemistry learning textbook in improving students’ learning outcomes. Therefore, this textbook can increase students’ imagination in understanding chemistry concepts and can improve students’ critical and creative thinking skills. Therefore, this textbook can be applied by chemistry teachers in improving students’ learning outcomes.

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