

## The Utilization of Pictorial Analogy and Colored Sticks in Chemical Equations

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### **Abstract**

Chemical Equations are valuable tool for helping students comprehend chemical reactions, as these reactions are intricately connected to human activities. The analysis of blood and tissue samples, the dating of fossils, the investigation of antiquity, and the detection and characterization of planets are a few of these chemical reactions. In order to understand more about how well students understood chemical equations using the coloured stick model and pictorial analogies, this study employed a quasi-experimental methodology. This research design, sought to establish a cause-and-effect relationship because groups were not randomly assigned. Two sections of Grade 10 students participated in this study as respondents, and they were selected depending on their availability and willingness to participate in the study. It was discovered that the difference in scores gained by the two groups is statistically significant. The computed absolute value of  $t$  (-4.09) is higher than the  $t$ -critical (2.08) with a  $p$ -value of 0.00, lower than the level of significance of 0.05, which proved that the pictorial analogy group performs better than the coloured stick group. It is recommended that, whenever applicable, the model be repeated in a variety of chemistry topics and courses that frequently use numerical presentation.

Keywords: Analogy, Chemistry Education, Chemical Equation, Science Teaching, Quasi-experiment

## INTRODUCTION

Chemical equations are fundamental to expressing chemical reactions and serve as the cornerstone of chemistry (Hussein, 2018; Henriksen & Hansen, 2018). They provide an effective means of learning about chemical reactions, helping to facilitate students' understanding of chemistry. During a chemical reaction, new molecules are formed through the formation of chemical bonds between the molecules of the reactants (Srisawasdi & Panjaburee, 2019).

Many of these chemical reactions are necessary for analysing blood and tissue samples, dating fossils, analysing ancient materials, and identifying and describing planets (Helminstine, 2019).

Chemical reaction is a fundamental process applied in industry, networks, and even in the field of nanotechnology. It is a detailed mechanism of chemical reaction used for the development of a water pollution diffusion modelling system for industrial facilities (Issakhov et al., 2020; Meierhofer & Fritsching, 2021).

The sophistication of the field of nanotechnology has grown exponentially as a result of this reaction process and has been applied to medical diagnostics for identifying bacteria. (Simmel et al., 2018). The cement industry, responsible for the emission of anthropogenic

greenhouse gases, is the leading producer of carbon dioxide in its manufacturing process, which is calcination (Miller et al., 2021). The understanding of the chemical reaction in its calcination process was the key element that paved the way for the development of the Computational Fluid Dynamics (CFD) model for its solution to lower pollutant formation and reduce greenhouse gas emissions (Mikulcic et al., 2012). Thus, chemical reactions have a significant impact on human lives, the development of networks and industries, and even technology (Aazam et al., 2018; Liang et al., 2019; Concepcion et al., 2022).

Chemistry, according to Reid (2021), is difficult and demanding for students not only in the basic education level but also in the tertiary level (Mangubat & Picardal, 2023). Its nature and the nature of learning itself are the major problems. The large number of compounds and the bewildering number of structures make it very apparent that students experience information overload, or the number of ideas that must be held in the mind at one time in order to gain understanding (Mangubat & Picardal, 2023). One of the difficult areas mentioned is redox, molecular, and thermodynamics. Redox is one of the topics included in discussing chemical reactions at the junior high school level (Schnoebelen et al., 2018).

Chemical reactions are described by a chemical equation that gives the identity and quantity of the reactants and products involved in the reaction. Atoms, molecules, molecular formula, atomic structure, bonding, valency, subscripts, and coefficients are concepts utilized in writing chemical equations that make it a complex topic (Dula, 2018). Disinterest in these chemical symbols and numbers can impede students' willingness to comprehend the topic (Jeffery et al., 2020; Lapitan et al., 2021; Abdh Ghani et al., 2022). Furthermore, difficulties in understanding may cause students to withdraw from the science classroom or to stop trying to learn at all (Dare et al., 2018; Loughran, 2018).

Science consists of topics that range from concrete to abstract, and it is the students' ability to relate to and see images of the concepts that makes the learning meaningful (Falloon, 2019; Picardal, 2019; Chan et al., 2018; Mustacisa, 2016). Poor methodology in science education and a negative attitude toward science subjects among students are the common reasons that contribute to poor performance (King'aru, 2014; Toma & Greca, 2018; Tabotabo-Picardal & Paño, 2018; Empiengco & Mustacisa-Lacaba, 2022). Therefore, the best strategies must be used that are appropriate to the curriculum, topic, cognitive abilities, and interests of

learners (Picardal & Sanchez, 2022). According to Kersting and Steier (2018), one of the teaching strategies that is helpful in teaching science is pictorial analogy, but very few people use it. Analogy is an important tool used by the teacher mostly when expounding hard and abstract discussions in physics, chemistry, and biology inside the classroom (Akca, 2016). Pictorial analogy is defined by Purnomo and Fauziah (2018) as the use of images from two different domains that are unfamiliar as the target and familiar objects as the source and bridging them. Usually, this strategy is used for topics that have lots of abstract concepts. A study of Chen and She (2020) found that students who received pictorial analogies in learning science demonstrated more integration behaviours and a better understanding of the concept than textual learners.

In the Philippines K-12 Curriculum Guide, chemical reaction is in the 4<sup>th</sup> quarter and the 24<sup>th</sup> competency, which is the last among all the competencies. This is the reason that this topic has been included in the six consecutive yearly reports in the School Monitoring Evaluation and Assessment (SMEA) as the least learned skill in science 10 due to its difficulty. Furthermore, due to time constraints, teachers tend to limit or avoid discussing the topic entirely.

In the context of the study Malindog (2020), most of the 10<sup>th</sup> grade students in junior high school at a school in Samar, Philippines, showed negative performance when learning chemical equations. They lacked independence, interest, and understanding of the subject. In fact in the studies of Tus (2019) and Macaso and Dagohoy (2022), almost all the students were relatively unsatisfactory (75–79 percent) when calculating their examinations for the fourth quarter due to difficulty in understanding concepts related to chemical equations.

Since chemical reactions are frequently identified as one of the least mastered skills in the aforementioned region, it is imperative that teachers utilize the most effective teaching techniques when instructing students on this subject.

Thus, failing to apply the best strategy in the teaching of...would result in a classroom with students performing poorly (Chang & Hwang, 2018). To address this school-based problem, a pictorial analogy model is suggested for use in teaching chemical equations. The pictures that would be used must be contextualized and localized so that students may easily refer to them or relate to them, and they would really serve as an effective analogy.

This study was conducted to investigate the effectiveness of using pictorial analogies, such as coconut shells, bamboo sticks, sweet potatoes, and green mussels, in teaching chemical equations. This approach had not been previously studied in educational research, and the use of locally contextualized materials was unique to the study's specific location.

This coloured stick model had already been used by Malindog (2020), and so the researcher used the pictorial analogy in this study. This study compared the gains in scores with the use of pictorial analogy and the coloured sticks model among Grade 10 students at a school in Samar, Philippines. This study hypothesized that pictorial analogy groups would outperform the coloured sticks model.

## **METHOD**

### **Research Design**

This study utilized a quasi-experimental design to obtain data on the effects of pictorial analogy and the coloured stick model in teaching chemical equations to student respondents. This research design attempted to establish a cause-and-effect relationship different from a true experiment because groups were not randomly assigned (Thomas, 2020). The respondents in this study were two groups of Grade 10 students (22 students

for each group), and due to the difficulty in gathering data because of the current constraints caused by the COVID-19 pandemic, the researcher chose the respondents as a pictorial analogy and coloured stick group based on their sections, which was a non-random assignment. This was the reason that quasi-experimental research was conducted. The participants were selected according to their availability and willingness to participate (Baumgardt et al., 2021).

#### **Data Collection Method**

The instrument that was used in the study was a 15-item multiple-choice questionnaire for the pre-test and the same for the post-test. The questions revolved around identifying elements and compounds, balancing chemical equations, and predicting the products of reactions. The instrument was adapted from Malindog's (2020) test questionnaire. This test was used to identify students' understanding of the topic, which was the chemical equation.

The first module was taken from Malindog's (2020) study, which used a coloured stick intervention model, while the second module was created by the researcher and used a pictorial analogy model. The pictures used were contextualized and were products of the research locale. The *tahong* meat or mussel, *tahong* shell, bamboo sticks,

sweet potato, and coconut shell were used as an analogy.

The first module had the intervention, which was the coloured stick model for the first group and the pictorial analogy model for the second group. The module was anchored on the standards set by the Department of Education (DepEd). Since modifications were made by using the contextualized resources, they were content validated by the chemistry professor at Samar State University.

The paper includes examples of items in the module that utilize the two analogies, as depicted in Figures 1, Figure 2, Figure 3, and Figure 4. It is important to note, however, that not all items are displayed in the paper due to intellectual property considerations. Interested readers can request complete access to the materials from the author.

#### **Validation of Instrument**

The pre-test and post-test that were given to the student respondents had first been submitted to the advisor of the researcher for checking. It was a 15-item multiple-choice test. It was subjected to expert content validation for inputs, suggestions, and recommendations.

The two modules, which had the intervention of a pictorial analogy model and a coloured stick model, were made based on the K-12 curriculum guide of the DepEd. The researcher then

submitted them to the experts and, after checking, proceeded to the validator. One of the chemistry professors had validated the modules. Suggestions and feedback were incorporated into the modules. When experts approved the modules, they were then ready to use.

### **Research Sample**

The study participants were 44 Grade 10 high school students from two classes with the same teacher. One class was assigned to the colored stick group ( $n = 22$ ), while the other made up the pictorial analogy group ( $n = 22$ ). Chemical equations are usually taught in Grade 10 because this is the grade level at which students typically begin to learn more advanced topics in chemistry. At this stage, students have typically developed a basic understanding of the fundamental principles of chemistry, including atoms, molecules, and chemical reactions.

The groups were selected by their advisers based on their final grades in 9<sup>th</sup> grade; those who had the lowest grades were the samples of the study. The group was assigned heterogeneously. Therefore, the knowledge level of the two groups of students was similar. The age of the students in the study ranged from 15 to 21. A coin toss was used to determine the order of treatment administration, with the Hermes group receiving the first treatment if the coin

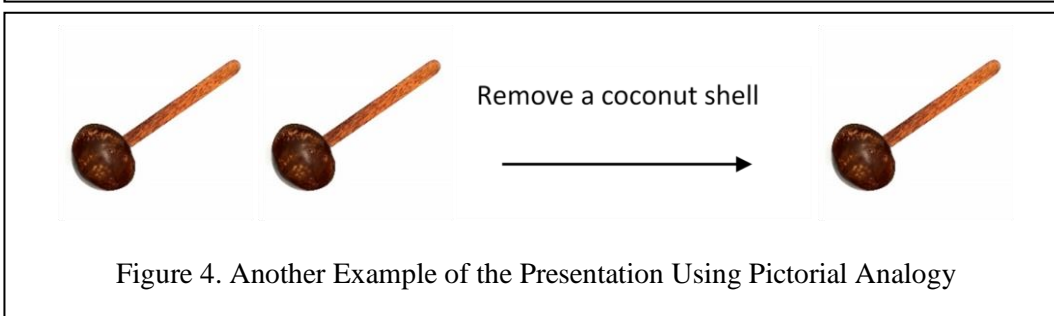
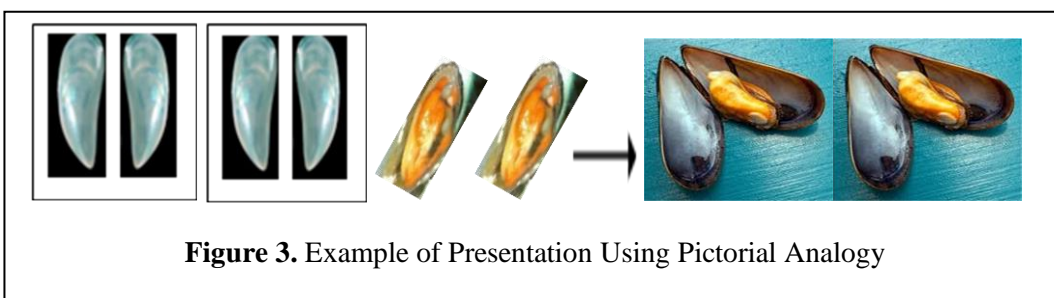
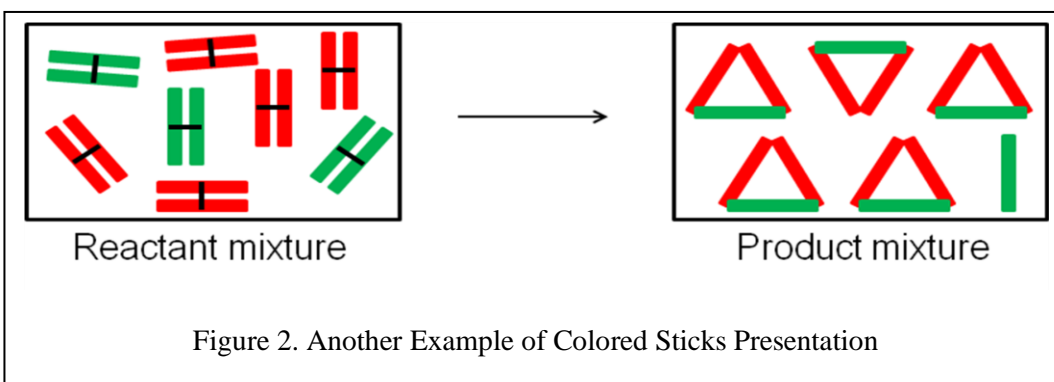
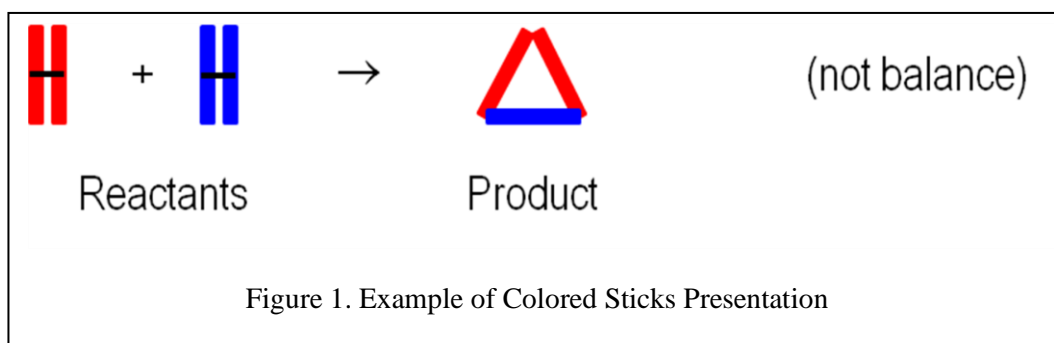
landed on heads. The Athena group served as the control or experimental group for the study. If the tail would manifest when tossed, the researcher would do the same. So, one of them was randomly chosen as the Coloured Sticks Group, which was the group Hermes, and the other as the Pictorial Analogy Group, which was the group, Athena.

### **Data Analysis**

The data gathered from the respondents were tallied, analysed, and interpreted. The researcher used descriptive statistics like frequency count, mean, and standard deviation to analyse and interpret the evaluation of results done by the expert. The researcher used a paired t-test to assure the appropriateness of the inferential statistics with a 0.05 level of significance.

### **Ethical Consideration**

Upon gathering data for this study, the researcher observed and complied with the ethical considerations. The data that were collected had been treated with the utmost confidentiality, and the researcher first asked permission from the authorities involved before conducting the study. Consent forms were also provided to the parents of the study samples, along with the consent forms of the students.



## RESULTS AND DISCUSSION

### Pre-test Mean Score Differences for Pictorial and Coloured Sticks Groups

According to the data in Table 1, of the 15 items on the pre-test, the group that was to be subjected to the coloured

stick model has a higher mean (4.77) than the group that was to be subjected to the pictorial analogy (3.55), but the difference is not statistically significant, implying that both groups are not yet familiar with the topics undertaken prior

to exposure to the two approaches, the use of coloured sticks and the use of pictorial analogy in teaching chemical equations.

In this case, both groups have minimal prior knowledge for the topic "chemical equation" based on their mean scores, which are 4.77 out of 15 (31.8%) for the coloured stick group and 3.55 out of 15 (23.7%) for pictorial analogy. Literature studies (Camble, 2016; Marin et al., 2019; Cooke & Conelas, 2019) confirmed these results as normal for those who first encounter the topic, chemical equation since it requires decoding complexity and skills such as mathematical ability and comprehension strategy to approach the concept. It is a suggestion that more than just numerical presentation, pictures, and analogies

should be used, especially in high school (Tsaparlis, 2018; Wu & Yeziarski, 2022).

### Post-test Mean Score Differences for Pictorial and Coloured Sticks Groups

The mean score for the post-test for the group exposed to the coloured stick model (12.73) and those exposed to the pictorial analogy (12.64) are comparable, as can be shown from Table 2, out of 15 items with a similar number of questions facilitated during the pre-test. These two methods are graphical symbols in general. These findings support earlier results from the pre-test that, in addition to numerical presentation, images and analogies should be included for chemical equations, according to Tsaparlin (2018) and Wu and Yeziarski (2022).

Table 1. Statistical Difference of Pre-test Scores between Two Groups

Group	Mean (Pre)	SD	t-critical	Computed t-value	p-value	Interpretation
Colored Stick	4.77	1.77	2.08	-0.005	0.996	Not Significant
Pictorial	3.55	1.79				

Legend: Significant at 0.05\*

Table 2 Statistical Difference of Posttest Scores between Two Groups

Group	Mean (Post)	SD	t-critical	Computed t-value	p-value	Interpretation
Colored Sticks	12.73	1.78	2.08	0.002	0.998	Not Significant
Pictorial	12.64	1.76				

Legend: Significant at 0.05\*



### Gained Mean Score Differences for Pictorial and Coloured Sticks Groups

Table 3 displays the gained mean scores (the difference between the post-test and pre-test scores) for the groups that were exposed to the pictorial analogy and coloured stick models. The data shows that the gained mean scores for the pictorial analogy group ( $\mu=9.09$ ) are higher than the gained mean score for the coloured stick group ( $\mu=7.95$ ).

The difference in scores gained for the said groups is statistically significant, as shown in Table 4. The computed absolute value of  $t$  (-4.09) is higher than the  $t$ -critical (2.08) with a  $p$ -value of 0.00, lower than the level of significance of

0.05, which proved that the pictorial analogy group performs better than the coloured stick group.

This confirms the previous claim by Akcay (2016) that pictorial analogy is one of the teaching strategies that is helpful in teaching science. Analogy is an important tool used by the teacher, mostly when expounding hard and abstract discussions in chemistry and other sciences. This is also similar to the claim made by Chen and She (2020) that students who received a pictorial analogy in learning science demonstrated more integration behaviours and a better understanding of the concept than textual learners.

Table 3 Gained Scores of Pictorial and Colored Sticks Groups

Colored Stick			Pictorial Analogy		
Post-test Score	Pre-test Score	Gained Score	Post-test Score	Pre-test Score	Gained Score
13	3	10	13	4	<b>9</b>
14	3	11	13	2	<b>11</b>
15	8	7	14	1	<b>13</b>
13	4	9	12	4	<b>8</b>
13	5	8	14	3	<b>11</b>
8	4	4	8	2	<b>6</b>
15	7	8	9	5	<b>4</b>
14	5	9	14	4	<b>10</b>
10	3	7	14	2	<b>12</b>
12	6	6	14	4	<b>10</b>
12	7	5	11	3	<b>8</b>
12	5	7	15	8	<b>7</b>
14	6	8	12	4	<b>8</b>
14	7	7	13	4	<b>9</b>
15	4	11	14	4	<b>10</b>
12	3	9	13	3	<b>10</b>
12	2	10	14	2	<b>12</b>
15	6	9	13	3	<b>10</b>
11	4	7	13	7	<b>6</b>
13	4	9	12	6	<b>6</b>
12	7	5	13	2	<b>11</b>
11	2	9	10	1	<b>9</b>
$\mu=12.73$	$\mu=4.77$	$\mu=7.95$	$\mu=12.64$	$\mu=3.55$	$\mu=9.09$
SD=1.78	SD=1.77	SD=1.89	SD=1.76	SD=1.79	SD=2.29

Table 4 Statistical Difference of Post-test Scores between Two Groups

Group	Mean (Gained)	SD	t-critical	Computed t-value	p-value	Interpretation
Colored Sticks	7.95	1.89	2.08	-4.09	0.00*	Significant
Pictorial	9.09	2.29				

Legend: Significant at 0.05\*

## CONCLUSION

Although the students who experienced both the pictorial analogy and the coloured stick model scored higher, the pictorial analogy was more successful at teaching students how to understand chemistry as well as the chemical equation. It is believed that the use of pictorial analogies with frequently encountered materials in the community is necessary to improve students' understanding of the concept of chemical

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equations. The findings from this study suggest that visualization with a contextualization approach of available community resources contributes to students' success in improving performance, particularly on topics with abstractness and complexity like chemical equations. It is recommended that the said model, whenever applicable, be repeated in a variety of chemistry topics and courses that frequently use numerical presentation.

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