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Designing Experiments on Chemical Kinetics using Common Household Materials: Perspectives of STEM High School Teachers

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Abstract

Due to remote learning, chemistry laboratory experiments have been difficult to implement. With this, the study explored the design of experiments on chemical kinetics that can be conducted at home. Seven STEM high school teachers participated in the study and underwent the process of designing the aforementioned experiments. Their experiences showed that they consider material availability in formulating the at-home activities. The design of their experiments underwent several processes: (1) making the flowchart, (2) conducting the pilot test, (3) illustrating the interactions in the particulate level, (4) writing corresponding chemical equations, (5) answering the experiment goal, and (6) finalizing the lab worksheet. In conclusion, high school teachers can design experiments on chemical kinetics and be trained for the macro-micro-symbolic understanding of chemical phenomena and the thorough design process ensures the possibility of implementing these home-based experiments to the students in remote learning. Training on home-based experiment design and development is recommended for schools in the Philippines.

Keywords chemical kinetics, design process, experiment design, high school teachers

INTRODUCTION

Experiments are essential components of Chemistry education as students gain macroscopic experience, where process skills are used in hands-on activities [1-3]. However, the conduct of experiments has become challenging for teachers, especially at the STEM-secondary level, because of the restrictions brought by the COVID-19 pandemic [4]. Although online demonstrations and virtual laboratories are available, some students lack access to the Internet and prefer modular remote learning as a means of schooling in the new normal [5]. In modular learning, experiments may be considered impractical but when the materials to be used are found at home, these experiments become possible [6].

Availability of materials is one of the considerations when planning for experiments to be done at home. The materials should be readily available at home or accessible to buy and safe to use by the students [7]. When these materials are available, the at-home experiments can provide opportunities for improved learning and skills development among the students [8]. Hence, home-based experiments can be possible activities for pre-college STEM students, particularly on chemical kinetics.

Chemical kinetics studies rates of chemical reactions, wherein studies have been conducted that developed experiments for this field for educational purposes [9-10]. However, the researcher has not encountered a study that aimed to develop home-based activities for remote learning. Therefore, this present study explored the development of these activities as designed by STEM high school teachers for their students. Specifically, it sought to characterize the process of developing these experiments as well as to evaluate the experiments based on the perspectives of the teachers.

The results of the study are beneficial to students, teachers, and school administration alike because chemical kinetics is one of the learning units in General Chemistry for the pre-college STEM curriculum [11]. Teachers could give meaningful macroscopic experiences to students as the latter continue learning Chemistry during remote learning in the new normal; thus, the conduct of this study.

MATERIALS AND METHODS

The study employed the descriptive research design, where seven STEM high school teachers from Central Visayas, Philippines participated in the development of the experiments on chemical kinetics using household materials. They are aged between 21-30 years old, mostly females, and currently pursuing graduate chemistry education at a state university in the same locale.

Informed consent was asked from the teachers and once they agreed to participate voluntarily in the study, they were oriented to the process of designing the experiments. The goal of the experiments was to determine the factors that affect the rates of chemical reactions and the focus was on the nature of substances, temperature, concentration, and surface area. After designing the experiments, they pilot-tested the activities by conducting these experiments by themselves. Results from the experiments were noted and evaluated whether the expected outcomes were obtained. Afterward, insights were asked from the teachers to describe their experiences in designing and conducting the home-based experiments.

RESULTS AND DISCUSSION

The STEM high school teachers designed experiments for observing and inferring the factors that could affect reaction rates. Teachers considered several aspects when designing the experiments such as the *safe conduct* of the experiments, *the role of parents* in the home-based activities, and *learning* that they can derive from doing the tasks by themselves. However, they emphasized the importance of *proper identification and selection of materials* for the experiments [7] and highlighted the use of common household materials as well as the possible alternative materials when the former is not available (Table 1).

Table 1. Common household materials used in the experiments

Exp. No.	Factor	Materials
1	Nature of Substances	muriatic acid (HCl), milk of magnesia ($Mg(OH)_2$), copper wire (Cu), zinc-coated staple wire (Zn), thumb tacks (iron, Fe)
2	Temperature	vinegar (HCH_3COO), water (H_2O: hot, cold, room temp.), corroded screw (Fe_2O_3)
3	Concentration	water (H_2O), muriatic acid (HCl), stape wire (Zn), dolostone
4	Surface Area	muriatic acid (HCl), antacids (pulverized, ¼ size, ½ size)
5	Catalyst	agua oxigenada (H_2O_2), muriatic acid (HCl), milk of magnesia ($Mg(OH)_2$)

After the identification and selection of materials and some alternatives, the teachers proceeded to the design of the experiments, In the development of these experiments, they underwent several processes to ensure not only the validity of the activities but also the extent of their understanding of chemical kinetics across macroscopic, microscopic, and symbolic levels. There are six identified processes, starting with the formulating of the steps in the experiments to finalizing the laboratory experiment worksheet.

Visualizing the steps through a flow chart. Firstly, the teachers formulated the aim of the experiments and enumerated the steps for these experiments. After enumerating the steps, they arranged the steps to form a process and constructed a flow chart (Fig. 1). Flow charts have been used in scientific endeavors, including their use in facilitating the process of science investigations [12] and in identifying

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the activities required to execute a process [13]. Therefore, flow charts are an effective means of visualizing formulated steps and translating them into a process.

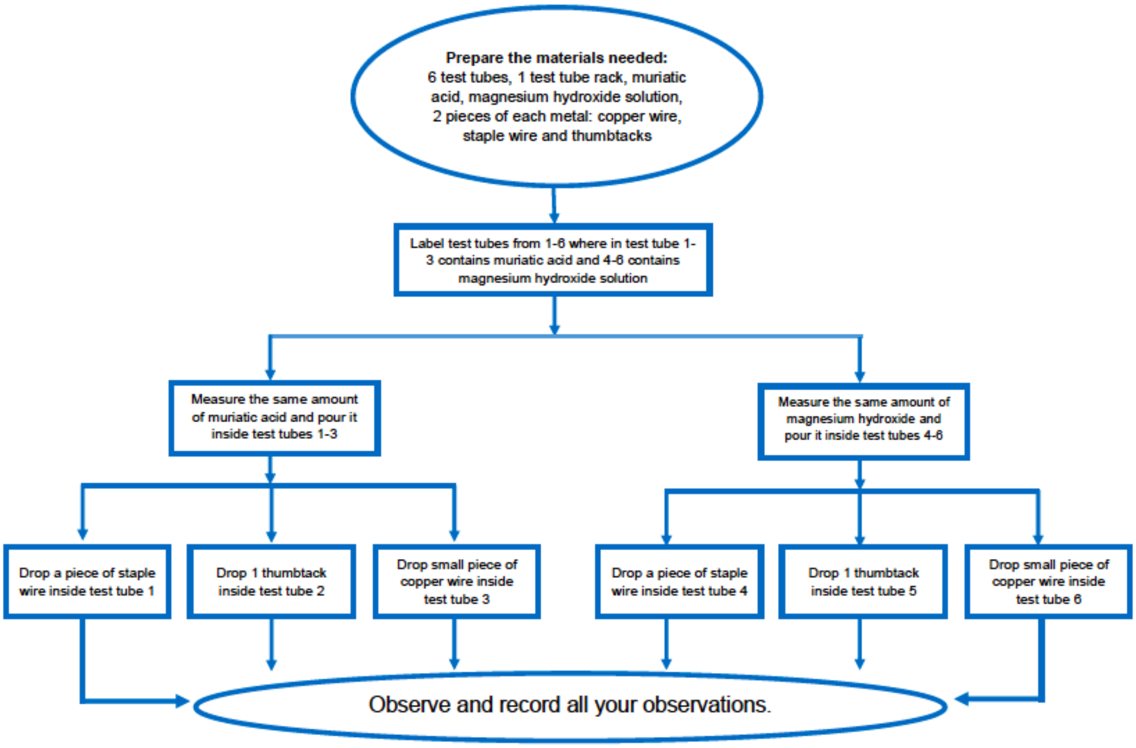

Fig. 1. Sample teacher's flowchart

Validating the designed experiment through pilot testing. The teachers then validated their designed experiments by conducting the experiments by themselves. They gathered the materials stipulated in the experiments, followed the procedures, and wrote their findings (Fig. 2). The conduct of experiments by the teachers themselves gives insights into the accuracy and reliability of the results obtained from the experiments as well as the other aspects of experimentation such as application of knowledge, degree of adult supervision, amount of time, among others [14]. Hence, pilot testing ensures that the experiments work before employing them to the students.

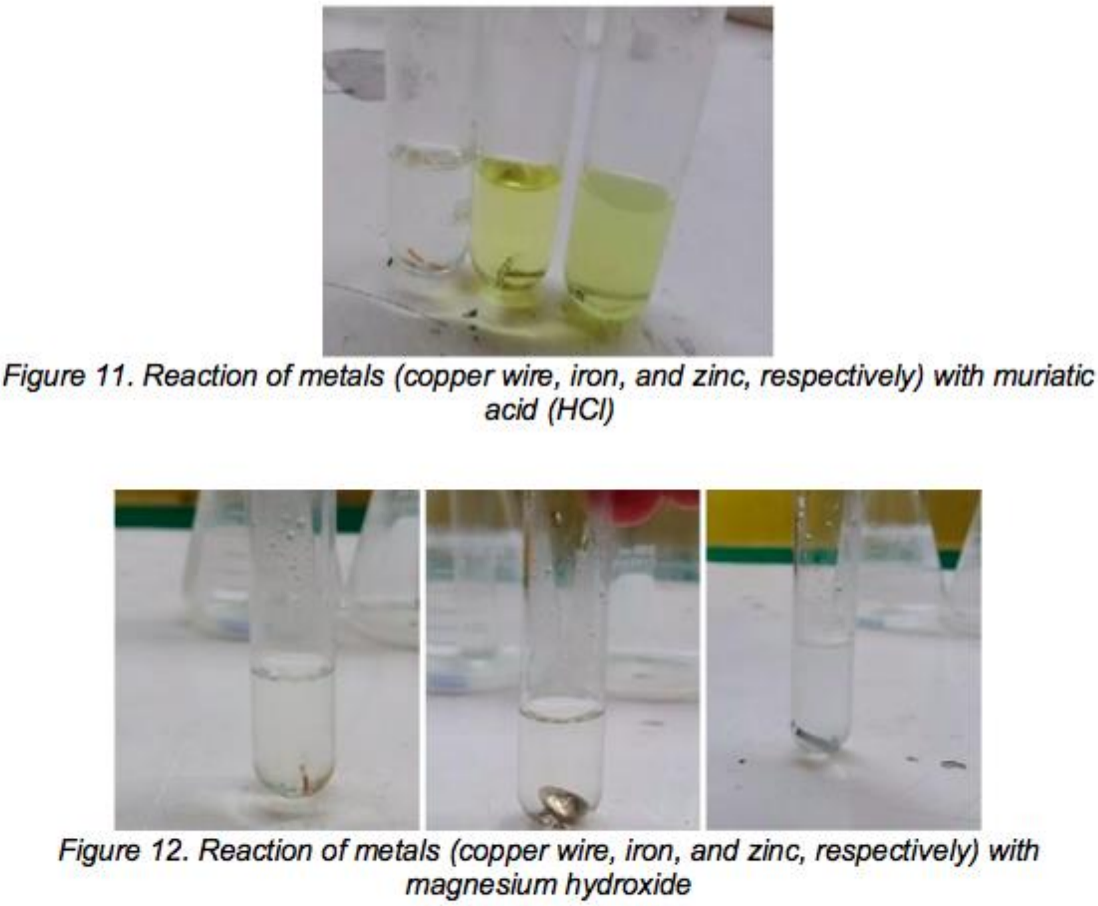

Fig. 2. Results based on the pilot testing

Illustrating the reactions through microscopic representations. Teachers also illustrated the interaction of the atoms or ions at the particulate level. This was to visualize the interaction when reactions occur at certain rates (Fig. 4). Microscopic mode supports macroscopic experience, wherein the behavior of particles is taken into account [1-3]. Through this mode, there is a close look at the mechanisms of reactions and their rate, contributing to a deeper understanding of chemical kinetics among teachers alike.

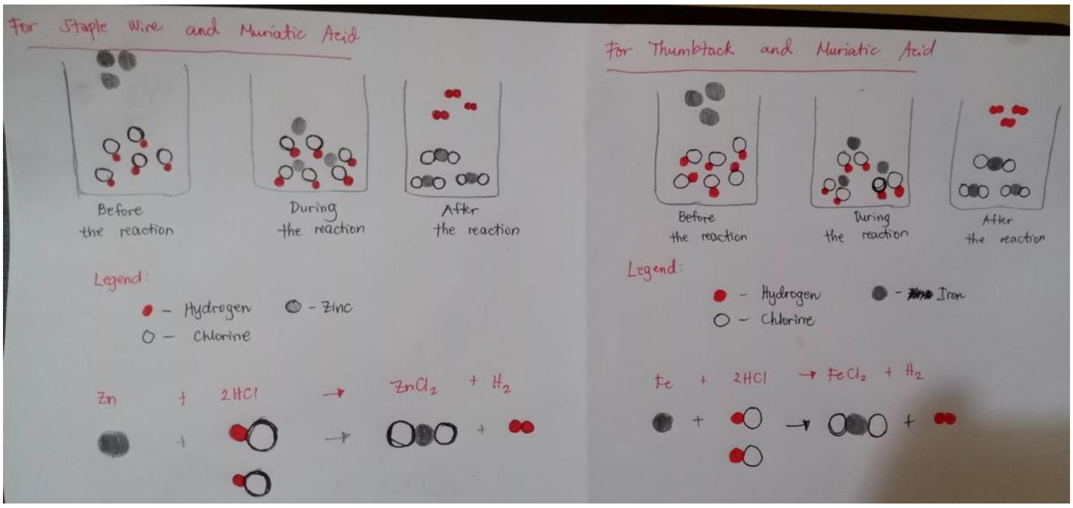

Fig. 4. Illustrations of the reactions at the particulate level

Writing the reactions using balanced chemical equations. To support the macroscopic and microscopic experience, teachers translated chemical reactions into balanced chemical equations. They wrote full and net ionic equations, showing the coherence of their experiments and illustrations to symbols (Fig. 3). The use of symbols connotes the abstract nature of chemistry, where chemical formulas and equations are used [1-3]. Including this step in the designing of experiments ensures that teachers have the skill of translating real-life experiences into symbols, resulting in a better understanding of chemical kinetics.

Copper wire in muriatic acid:

$$Cu(\mathrm{s}) + HCl(\mathrm{aq}) \rightarrow \mathrm{Noreaction}$$

Thumb tack in muriatic acid (iron as main component):

$$Fe(\mathrm{s}) + 2HCl(\mathrm{aq}) \rightarrow FeCl_2(\mathrm{aq}) + H_2(\mathrm{g})$$

$$Fe(\mathrm{s}) + 2H^+(\mathrm{aq}) \cancel{+ 2Cl^-(\mathrm{aq})} \rightarrow Fe^{2+}(\mathrm{aq}) \cancel{+ 2Cl^-(\mathrm{aq})} + H_2(\mathrm{g})$$

full ionic equation

$$Fe(\mathrm{s}) + 2H^+(\mathrm{aq}) \rightarrow Fe^{2+}(\mathrm{aq}) + H_2(\mathrm{g})$$

net ionic equation

Staple wire in muriatic acid (zinc as outer coating):

$$Zn(\mathrm{s}) + 2HCl(\mathrm{aq}) \rightarrow ZnCl_2(\mathrm{aq}) + H_2(\mathrm{g})$$

$$Zn(\mathrm{s}) + 2H^+(\mathrm{aq}) \cancel{+ 2Cl^-(\mathrm{aq})} \rightarrow Zn^{2+}(\mathrm{aq}) + \cancel{2Cl^-(\mathrm{aq})} + H_2(\mathrm{g})$$

full ionic equation

$$Zn(\mathrm{s}) + 2H^+(\mathrm{aq}) \rightarrow Zn^{2+}(\mathrm{aq}) + H_2(\mathrm{g})$$

net ionic equation

Fig. 3. Balanced chemical reactions based on the experiment

Synthesizing through answering the purpose of the experiment. Once teachers understood the experiment using the macroscopic, microscopic, and symbolic representations, they did the synthesis by addressing the purpose of the experiment. They identified, described, and explained the factors that affect reaction rates. By including this step in the process, they can be refreshed and updated on how to generalize based on the results of the experiments.

Finalizing the laboratory experiment worksheet. After undergoing the previous steps, the teachers revised their designs based on the results of the conduct of the experiments and finalized the worksheet for implementation in their classes.

CONCLUSION

Designing experiments on chemical kinetics is a process of developing laboratory activities using common household materials, and training teachers to use macroscopic, microscopic, and symbolic representations for better and deeper chemical understanding. Through the design processes teachers undergo, they ensure the feasibility and validity of implementing home-based experiments for remote learning. Training on home-based experiment design and development is recommended for schools in the Philippines.

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