Localized Litmus Paper and Computer Interactive Simulator in Teaching Acids and Bases

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ABSTRACT

This study aimed to determine the effectiveness of using localized litmus paper and computer interactive simulation in teaching the concepts of acids and bases. The respondents of the study are the grade seven students of a private school in Dumaguete City, during the academic year 2023-2024. The researcher utilized the descriptive, correlational, comparative, and Cluster-Randomized Controlled Trial (CRT) methods of research. This study also made use of researcher-made questionnaires that measured the performance of the students in using the two methods of instruction, respectively. The statistical tools used in this study include standard deviation, mean, t-tests for dependent and independent data, and Spearman's rho. The findings revealed that there is a significant improvement in the student's performance after using localized litmus paper ($p=0.001 < \alpha=0.05$) and computer interactive simulator ($p=0.000 < \alpha=0.05$). Overall, both methods of instruction proved to be vital and effective ($p= 0.597 > 0.05$) in the student's learning of the concepts of acids and bases. The results suggest that both approaches can be valuable tools for educators, enabling them to effectively cater to students' different learning styles or maximize teaching effectiveness through varied instructional strategies. While using both methods of instruction resulted in comparable posttest success, the usage must be coupled with classroom dynamics, a helpful learning environment, improved study habits of students, and teachers' positive behavior to achieve higher student performance. Additionally, the findings indicate that both methods are useful teaching tools that the Department of Education and various private basic education institutions can use in teaching acid-base lessons.

Keywords: *Localized apparatus; Computer interactive simulator; Litmus paper; Acids and base; Methods of instruction*

Introduction

Since the dawn of civilization, science has served as a crucial tool for understanding the world. With rapid technological advancements, scientific literacy is becoming more crucial than ever, enabling individuals to function effectively in a society that is heavily influenced by science (Solomo, 2020). However, research suggested a continuing decline in science literacy at all academic levels (Glaze, 2018). In fact, a lot of researchers have raised concerns about the constant decline in students' interest in scientific careers, including in countries like Australia, parts of the Western World, and several ASEAN nations (Leung & Zhu, 2011; Muruyama et al., 2013; Chang, 2014; NSF; 2018; Fuente, 2019).

This global trend is mirrored in the Philippines, where learners' scientific knowledge has been observed to be in decline, as clearly shown in the 2018 and 2022 Programme for International Student Assessment (PISA) results. PISA evaluated the performance of 15-year-old learners in reading, mathematics, and science and showed that the Philippines landed in the second-lowest spot in the science exam (PISA, 2018; PISA, 2022; Bernardo et al., 2023). This low performance was also demonstrated by the Filipino fourth graders who participated in the Trends in International Mathematics and Science Study (TIMSS) 2019 cycle, earning the lowest score among all 58 participating nations. The results further indicated that only 19% of pupils from the Philippines obtained scores categorized as low standard or better, which means that most Filipino pupils have low knowledge of scientific concepts and a limited understanding of basic scientific principles (Martin et al., 2020). The decrease in students' learning in science may be attributed to the lack of science laboratories, particularly chemistry laboratories, in the different regions of the Philippines (Estipular & Roleda, 2018; Noroña, 2021). This has affected the learner's grasp of the different concepts taught in their chemistry classes.

Laboratory activities enable students to comprehend the concepts in learning chemistry (Tuysuz, 2010; Orbe et al., 2018). However, due to the lack of laboratory supplies, equipment, and apparatuses in laboratories, hands-on experiments are rarely performed (Orbe et al., 2018). In response to this problem, researchers have tried exploring the use of localized apparatuses and interactive simulations. Balbon (2018), for instance, created a localized apparatus for geometrical optics and found it effective in improving students' academic performance. Similarly, Patron and Despojo (2020) did inexpensive demonstrations and experiments to augment understanding of the basic concepts of fluid mechanics.

Meanwhile, several researchers focused their studies on the integration of interactive simulations with science lessons (Yucor, 2018; Falloon, 2019; Dionson, 2020; Atsuwe & Azande, 2020; Laurence, 2022). Other local researchers even studied the use of both localized apparatuses and interactive simulations in biology (Cabuyoc, 2020) and physics (Jose Acabal, 2019; Joharaj Acabal et al., 2022). However, no similar studies focusing on chemistry have yet been done. Although Tatli and Alipasa (2012), An et al. (2019), and Chan et al. (2021) examined the impact of interactive simulation on chemistry lessons, the use of localized apparatus in teaching chemistry has not been widely studied, since previous research mostly focused on other science lessons. Therefore, this study was conducted to evaluate the students' performance, particularly in learning acids and bases using localized litmus paper and a computer interactive simulator.

Acids and bases, among other lessons, are discussed in the seventh-grade science subject, based on the DepEd K-12 Curriculum Guide (2016). These lessons allow students to understand the effects of acid and base compounds on the balance of life on Earth. Examples of natural phenomena showing the significance of these compounds are ocean acidification (Jiang et al., 2019) and soil pH, which affect plant growth (Neina, 2019). The researcher believes it is important to develop a method of instruction and instructional materials, such as localized litmus paper and a computer interactive simulator, to further enhance the students' learning.

Methodology

Research Design

The research design is descriptive, correlational, and comparative. Additionally, the Cluster-Randomized Controlled Trial (CRT) was applied. It is descriptive because of the following: (a) it describes the pretest and post-test performance of the students before and after using the localized litmus paper and computer interactive simulator; and (b) it describes the students' level of interest in using the localized litmus paper and computer interactive simulator. It is also correlational because it attempts to relate the students' interest to their post-test performance in acids and bases using the localized litmus paper and computer interactive simulator. The study is also comparative since (a) the pretest and post-test performance of the students in using each method of instruction were compared, and (b) the post-test performance of the students in using the localized litmus paper and computer interactive simulator. Moreover, the study applied the Cluster-Randomized Controlled Trial (CRT) because the individual students were not randomly assigned to the groups. Rather, the groups were created based on the students' previous grades in science (grade six overall science grade) and were each randomly assigned a method of instruction.

Research Locale

This research was carried out at a private school located in Dumaguete City, Negros Oriental.

Research Participants

Thirty-two (32) Grade 7 students enrolled in the school served as the respondents of the study. These students were divided into two groups (clusters) based on their prior knowledge. The researcher then applied the one-stage cluster sampling technique and randomly selected a method of instruction for each of the two groups. For example, if the localized litmus paper is randomly assigned to the first group, then every student in this group or cluster becomes a part of the experiment. The same procedure was done for the second group.

Research Instrument

The instruments utilized in the study are localized litmus paper, a computer interactive simulator, an activity guide, and questionnaires. The researcher used the computer simulator called pH Scale Simulation Software, which was downloaded from Phet Colorado (phetcolorado.edu) and was used in the experiment with the aid of an activity guide made by the researcher. Furthermore, the researcher constructed a questionnaire to assess students' performance in acid-base lessons. The sets of test questions were created using a Table of Specifications (TOS). The test questionnaire was validated by four different experts in the field, after which a dry run was conducted. The results of the dry run underwent a reliability test through item analysis before the final experiment.

Data Gathering Procedure

Along with the endorsement of the dean of Foundation University Graduate School, a letter of request to conduct the study was sent to the University Chancellor for Academic Affairs. The signed and approved request was then presented to the school principal and respective advisers of the grade seven students of the targeted school. During the actual data gathering, the researcher made sure that the disclosure statement was attached directly to the questionnaires right before the respondents began answering them. This was done to ensure the confidentiality of the data and to keep the respondents aware of their roles before the conduct of the study. The disclosure statement also served as proof of their consent to participate in the study.

Before the conduct of the experiment and the distribution of the test questionnaires, the researcher clearly explained to the students the purpose and importance of the research. This was done to guarantee a smooth flow of the experiment. Proper protocols were also strictly observed by the researcher.

During the conduct of the three-day experiment, a timetable was followed—one hour for the first day, one hour for the second day, and one hour for the third day. On the first day, the researcher thoroughly discussed the lessons on acids and bases. On the second day, the researcher explained the procedure of the activity and let the students manipulate the localized litmus paper and computer interactive simulator with the support of the activity guide. On the third day, the post-test questionnaire was distributed to the students. Afterward, the results were analyzed and interpreted.

Ethical Considerations

The respondents of the study were fully informed about the intention of the study. They were left to decide whether they wanted to participate or not. Confidentiality of information, such as the respondents' grades and personal data, was strictly upheld. In cases where the respondent would wish to terminate his or her participation in the study, he or she would be given one month to do so. After the lapse of the given period, all information would be kept private and anonymous. The researcher assured all the respondents that they would not be subjected to any harm during the duration of the study.

Results and Discussion

Pretest Performance of the Two Groups of Students

Table 1 presents the data signifying the pretest performance of the students before using the localized litmus paper and computer interactive simulator in learning the acid and base lesson. The data show that the average academic performance rating of the students before the utilization of localized litmus paper was 72%, whereas the students who utilized a computer interactive simulator only had a 70% rating.

Table 1. Pretest performance of the two groups of students

Rating (%)	Verbal Description	Localized Litmus Paper Group (n=16)		Computer Interactive Simulator Group (n=16)	
		f	%	f	%
75 – 79	Fairly Satisfactory	12	75.00	3	18.75
≤ 74	Did Not Meet Expectations	4	25.00	13	81.25
Mean		72.08% (Did Not Meet Expectations)		70.33% (Did Not Meet Expectations)	
SD		2.94		3.28	

These findings indicate that both groups struggled with their understanding and pre-requisite knowledge and that they have not adequately acquired or developed the fundamental knowledge and skills to aid their understanding of acids and bases. Furthermore, the data reflect the standard deviations (SD) of the students' performances before using the localized litmus paper and computer interactive simulator. The localized litmus paper group had a standard deviation of 2.94, while the computer interactive simulator group had 3.28, both of which can be rounded off to 3.

Furthermore, the data suggest that both groups struggled with their understanding and pre-requisite knowledge and that their fundamental knowledge and skills had not been acquired or developed adequately to aid their understanding of the acid and base lesson before using localized litmus paper and computer interactive simulation. These data correspond with Patron and Despojo's (2020) findings, wherein the students' pretest performance "did not meet the level of expectation" as far as their understanding of fluid mechanics concepts is concerned. They are also in line with the results obtained by Cabuyoc (2020), which showed that the student's pretest performance in the diffusion and osmosis lesson did not meet expectations.

Posttest Performance of the Two Groups of Students

Table 2 presents the posttest results of the students who used a computer interactive simulator and localized litmus paper. The data reveal that both groups are at "fairly satisfactory" levels as indicated in the mean percentage of 77.58% for the localized litmus paper group and 76.50% for the computer interactive simulator group. The results imply that the students at this level have met the minimum requirements in terms of skills in and comprehension of acids and bases. Nonetheless, the results also suggest that the students still need guidance throughout their performance of authentic tasks (DepEd Order No. 8, s 2015).

Table 2. Post-test performance of the two groups of students

Rating (%)	Verbal Description	Localized Litmus Paper Group (n=16)		Computer Interactive Simulator Group (n=16)	
		f	%	f	%
85 – 89	Very Satisfactory	1	6.25	2	12.50
80 – 84	Satisfactory	5	31.25	1	6.25
75 – 79	Fairly Satisfactory	6	37.50	9	56.25
≤ 74	Did Not Meet Expectations	4	25.00	4	25.00
Mean		77.58% (Fairly Satisfactory)		76.50% (Fairly Satisfactory)	
SD		6.18		5.26	

The data in Table 2 further reflect the standard deviations (SD) of the students' performances after utilizing the localized litmus paper and computer interactive simulator to learn about acids and bases. They indicate that the localized litmus paper group had a standard deviation of 6.18, while the computer interactive simulator group had a value of 5.26. This means that the student's performance in the posttest improved after using localized litmus paper and computer interactive simulation. These findings concur with those of Acabal (2019), Dionson (2020), and Duya (2021), who claimed that students' performance improved following the intervention relevant to learning difficult scientific concepts. Moreover, Yucor (2018), Cabuyoc (2020), and Acabal et al. (2022) also emphasized that utilizing the aforementioned methods of instruction had a positive impact on students' learning.

Nevertheless, it can be observed from the data that, although the students' academic performance improved after utilizing the litmus paper and computer interactive simulator, the improvement was not really that high. Indeed, secondary school students have difficulty in learning concepts in Chemistry, according to Siddique et al. (2022). That is why the use of litmus paper and computer interactive simulators as methods of instruction must be coupled with other factors such as classroom dynamics, helpful learning environment, better study habits of students, and teachers' positive behavior (Mangubat, 2023) to further enhance the student's performance in Chemistry.

Difference Between the Pretest and Post-test Performances of the Students

Table 3 shows the difference between the pretest and posttest performances of the two groups of students utilizing localized litmus paper and a computer interactive simulator in learning the concepts of acids and bases. As revealed, a significant difference exists between the pretest and posttest ratings of the students who were subjected to using localized litmus paper ($p=0.001 < \alpha=0.05$) in favor of the posttest performance.

Table 3. Analysis table on the difference between the pretest and posttest performances of the students

Groupings	Pretest	Posttest	Difference	p-value	Decision	Interpretation
Localized Litmus Paper Group	72.08	77.58	5.50	0.001	Reject H_{o1}	Significant
Comp. Interactive Simulator Group	70.33	76.50	6.17	0.000	Reject H_{o1}	Significant

Level of significance = 0.05

The results also depict that there is a difference of 6.17 between the pretest and the posttest performances of the students who were exposed to computer interactive simulation. Based on the data, the p-value (0.000) is less than the level of significance (0.05), which warrants the rejection of the null hypothesis. In other words, there exists a significant difference between the pretest and posttest performances of the students after they were taught the concepts using the computer interactive simulation activity.

The statistically significant improvement in the students' performance as shown in the posttest results can be attributed to the utilization of the localized litmus paper and computer interactive simulator. Balbon (2019), Patron and Despojo (2020), and Duya (2021) had similar observations that students' posttest performance would usually become higher than their pretest performance after being exposed to localized apparatus. Correspondingly, Acabal (2019), who utilized toys made from recyclable materials as learning resources, found a significant difference between the pretest and posttest performances of the students. In addition, Falloon (2019), Atsuwe and Azande (2020), and Mahawan and Celedonio (2023) have noted an increase in the students' academic performance, which also corresponds with the findings of Putri et al. (2021) and An et al. (2019), which reinforce the notion that virtual laboratories and augmented reality not only improve student learning outcomes in science and chemistry lessons, respectively but also serve as alternatives for physical laboratory equipment in some cases. On a similar stance, Tatli and Alipasa (2012) and Chan et al. (2021) postulated that virtual chemistry laboratories positively impacted the constructivist learning environment and were equally effective as real chemistry laboratories.

Difference Between the Post-test Performances of the Two Groups of Students

Table 4 displays the data signifying the difference between the posttest performances of the students utilizing localized litmus paper and a computer interactive simulator in learning acids and bases. Using a t-test for independent data, it is shown that the p-value ($p= 0.597$) is greater than the level of significance ($p> 0.05$). Hence, there is no significant difference in the posttest performance of the students who utilized localized litmus paper and computer interactive simulation in learning acids and bases.

Table 4. Analysis table on the difference between the pretest and posttest performances of the students

Groupings	Posttest	Difference	p-value	Decision	Interpretation
Localized Litmus Paper	77.58	1.08	0.597	Fail to reject H_{o2}	Not significant
Comp. Interactive Simulator	76.50				

Level of significance = 0.05

The current findings show that both the localized litmus paper and the computer interactive simulator can be utilized, as there is no significant difference between the post-test results of the two groups of respondents. These findings strengthen the results gathered by Mangubat and Picardal (2023), which revealed that practical laboratory experiments can increase students' performance in chemistry. Similarly, the study conducted by Yucor (2018), Cabuyoc (2020) and Joharaj Acabal et al. (2022) revealed no differences in learning between the different groups of students after being subjected to localized apparatus and interactive simulation as interventions in mathematics, biology, and physics lessons. Moreover, using localized litmus paper and computer interactive simulators as methods of instruction demonstrably supports Kolb's theory, which states that students gain concrete experience through interaction and new tasks (Konak, 2014).

These findings have great implications, especially for educational institutions located in remote places that have trouble gaining access to the Internet. Considering that there exists no significant difference between the use of localized litmus paper and interactive simulators, schools can opt to utilize the localized litmus paper since, technically, its effectiveness is almost like that of interactive simulation.

Conclusions

The two methods of instruction proved to be vital and effective in augmenting the students' learning of the concepts of acids and bases. Despite the pretest scores being rather low, the use of both the computer interactive simulator and the localized litmus paper as instructional materials demonstrated a considerable improvement in the posttest results. This means that both methods are valuable teaching tools that the Department of Education and private basic education institutions may use for teaching acid-base lessons to accommodate various learning styles and maximize efficacy through a variety of instructional strategies.

Contributions of Authors

The authors confirm their equal contribution to every part of this research. All authors reviewed and approved the final version of this paper.

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Conflict of Interests

All authors declared that they have no conflicts of interest as far as this study is concerned.

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