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Natural Acid-Base Indicators as Home-based Experiments: Feasibility, Satisfaction, and Teachers' Experiences in Secondary Science Blended Instruction

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Abstract: Natural Acid-Base Indicators as Home-based Experiments: Feasibility, Satisfaction, and Teachers' Experiences in Secondary Science Blended Instruction. Objectives: Common plants in the community can be used as acid-base indicators in laboratory experiments for blended learning in Chemistry. With this, the researchers conducted a study on the feasibility of the home-based experiments as well as the satisfaction and experiences of secondary-level teachers. **Methods:** Through a stratified random sampling from northern, southern, and metro Cebu in Central Visayas, Philippines, 45 teachers performed the experiment, answered the survey questionnaire, and were interviewed about their experiences. Data was collected and analyzed using descriptive and thematic analyses. **Findings:** The results showed that the home-based experiments were very feasible in terms of independent learning (μ=4.52, SD=0.50), resource availability (μ=4.25, SD=0.43), and safety considerations (μ=4.28, SD=0.68), as well as feasible according to adult supervision (μ=2.48, SD=1.06). Moreover, the experiments produced a very positive experience (μ=4.72, SD=0.40), which can be attributed to resource availability (ρ=0.574, p=0.000) and safety considerations (ρ=0.415, p=0.004). Furthermore, the teachers encountered opportunities, overcame challenges, and proposed improvements to the experiment. **Conclusion:** The home-based experiments on natural acid-base indicators are very feasible and highly satisfactory.

Keywords: acid-based indicators, home-based experiments, secondary chemistry blended instruction.

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INTRODUCTION

Many countries are transitioning toward post-COVID educational settings, including Southeast Asia and the Philippines (Klayprayong, 2021; Estrellado, 2021). Most schools have returned to face-to-face physical classes, which entail another shift of learning modality. Students and teachers adjust themselves from online learning to physical classroom interactions. Other schools mix the two modalities in a blended learning modality (Lapitan et al., 2021; Garcia-Bolaños et al., 2022; Villanueva et al., 2023). In blended learning, teachers and students can work on activities that can be done both in school and at home. One of the subjects that can implement this blended learning setup is science.

Science is crucial in post-COVID education (Rogayan & Dantic, 2021; Wang & Yuan, 2021). This subject lets the students investigate phenomena by undergoing the scientific method. In this method, they can find evidence and verify their hypotheses and assumptions through experimentation. Hands-on laboratory experiments help students learn science by connecting concepts learned in the classroom to real-life applications and encouraging scientific inquiry, reasoning, and critical thinking (Sanchez, 2017; Shana & Abulibdeh, 2020; Santiago et al., 2022; Supeno et al., 2022). However, these hands-on activities are rarely implemented in schools in the Philippines due to limited resources and time. Since the start of the face-to-face classes, the students have gone to school in shifts; some schools have two shifts while others have three (Sagarino, 2022; Jalil, 2022). This situation means that students learn in tight-knit 5-6 hours daily. With this, opportunities to conduct school experiments are limited (Lansangan, 2020; Rusmini et al., 2021; Velarde et al., 2022). One way to address this problem is through home-based experiments.

Also known as home-grown experiments (Pacifico & Prudente, 2021), kitchen-based experiments, do-it-yourself (DIY) experiments (Gya & Bjune, 2021), at-home experiments (Andrews et al., 2020), in-house experiments (Velarde et al., 2022), or take-home experiments (Santiago et al., 2022), home-based experiments allow students to observe and use readily available household materials to put the theory on practice. During the pre-COVID pandemic setups, home-based experiments have been shown to affect science learning positively. Obomanu and Akporehwe (2012) revealed that these home-related activities had enhanced students' performance on basic science concepts. In addition, Neves et al. (2017) concluded that home-based experiments in biology could contribute significantly to learning like physical experiments. Zulirfan et al. (2018) discovered that the experiments could enhance the students' scientific attitudes and values. Home-based experiments can improve learning across cognitive, affective, and psychomotor domains.

Home-based experiments have been crucial in learning science concepts during the pandemic. In the early stage of the pandemic, Pacifico and Prudente (2021) observed that students showed negative perceptions of their home-grown experiments, showing disinterest and lack of collaboration. However, home-based experiments have become helpful in the succeeding stages of the pandemic. Robledo (2021) investigated home-based biology experiments adapted for authentic remote learning and found that safety, tangibility, reflectivity, collaboration, affordability, and modifiability are essential attributes of the experiments. Gya and Bjune (2021) designed DIY experiments for plant biology and revealed that these experiments could be an excellent way to have a physical application to plant organisms, systems, or techniques.

Moreover, Chirikure (2021) studied home-based practical work and observed this set of activities to be contextualized and flexible, which can empower and enhance active science learning. Velarde et al. (2022) worked on in-house experiments and stated that adding these experiments can provide a complementary tool for understanding science, such as chemistry. Furthermore, Santiago et al. (2022) researched practical home work on wastewater treatment, and their study resulted in high motivation and positive learning outcomes in science.

In addition, home-based experiments can help students achieve a more scientifically accurate understanding of challenging lessons like acids and bases, which they encounter at home every day (Sanchez et al., 2021). The use of acid-base indicators helps understand the concepts of acids and bases. Natural acid-base indicators are an alternative to commercial ones because they are cheap, locally available, and environment-friendly. Natural acid-base indicators are pH indicators that originate from natural sources like specific plants' leaves, flowers, or fruits. Okoduwa et al. (2015) examined acid-base indicators from natural sources like the rose (*Rosa setigera*), allamanda (*Allamanda cathartica*), and hibiscus (*Hibiscus rosa-sinensis*), which are cheap, readily available, simple to extract, not toxic, and environmentally friendly. Kapilraj et al. (2019) analyzed the extracts of lesser bougainvillea (*Bougainvillea glabra*), garden balsam (*Impatiens balsamina*), and purple orchid tree (*Bauhinia purpurea*), signifying that these indicators can be extracted through the very simple, cost-effective, and environmentally friendly way. Sanchez et al. (2021) looked into common plants like cassava leaves (*Manihot esculenta*), piti-piti flowers (*Ruellia tuberosa*), and tomato fruits (*Solanum esculenta*), revealing that the tomato indicator can provide better results for acid-base indication tests. Reyes et al. (2022) utilized extracts from 11 plants, including plumeria flowers (*Plumeria rubra*), moringa leaves (*Moringa oleifera*), eggplant peelings (*Solanum melongena*), and chili fruit (*Capsicum frutescens*), concluding that these indicators are suitable for qualitative acid-base analysis. These natural sources contain organic substances that show distinctive colors depending on the acidity or basicity of a substance. Examples of substances that give different parts of plants their color include flavonoids, flavonols, anthocyanins, quinines, imines, and carotene (Kapilraj et al., 2019).

Based on the abovementioned literature, there have been gaps. The researchers have yet to encounter studies on home-based experiments implemented in blended learning modalities as an off-shoot of the learning shifts during the pandemic. In addition, the feasibility of home-based activities on acids and bases based on the student's immediate surroundings has yet to be explored extensively in the literature. Further studies are needed to ascertain the effectiveness of these activities at home and school. Finally, many plant materials readily available at home can be investigated for their acid-base indicator ability, providing a suitable medium where students can still conduct practical work even through blended learning abilities. With these gaps, the study was conducted to determine whether home-based experiments are feasible in blended chemistry learning setups. Specifically, the study determined (a) the level of feasibility of the experiment in terms of independent learning, resource availability, adult supervision, safety precautions, and satisfaction; and (b) the challenges, opportunities, and implications for blended science teaching.

The study is novel as it investigated home-based experiments in blended modalities and explored the relationship between variables such as independent learning, resource availability, adult supervision, safety precautions, and satisfaction. Aside from this, qualitative descriptions were included to deepen the understanding of implementing these activities in schools. Due to this novelty, the study can provide important implications to the new learning setup and inculcate the values of resourcefulness, respect for nature, and innovation, which are actual outcomes of science education not only in the Philippines but the whole world. With this, the study was conducted.

METHODS

Participants

The participants of this study were secondary school teachers (N=45) in Central Visayas, Philippines. Stratified random sampling selected the study participants. They were divided into three groups (n=15), each from major parts of research locale. The first group comes from Northern Cebu, the second group from Southern Cebu, and the last group from Metro Cebu. Northern Cebu worked on mayana leaves (*Coleus blumei*), Southern Cebu on tarnate flowers (*Clitoria ternatea*), and Metro Cebu on "lubilubi" or areca plam seed (*Areca catechu*). Each group (e.g., Northern Cebu) was divided further into five subgroups, which worked on their assigned natural indicator. Hence, there were 15 subgroups in the study, providing more reliability and validity in data gathering.

Research Design and Procedures

The researchers employed descriptive-correlational study in conducting this study. In this design, the feasibility and satisfaction variables were described and correlated. A descriptive qualitative analysis was held to deepen the understanding of these variables. Descriptive-correlational studies are robust in establishing the nature and relationship of variables under investigation, while descriptive qualitative can complement the correlational results of the study (Curtis et al., 2015).

The study procedure was adapted and modified from the study of Mapa et al. (1997) and Sanchez et al. (2021). A set of standard solutions with a pH of 1 to 13 was prepared in separate 100-mL beakers. About 600 mL of distilled water was boiled to prepare the pH 7 solution to remove any dissolved carbon dioxide. The 0.1 M HCl and 0.1 M NaOH were used for working solutions. The natural indicators were prepared separately by pounding four mayana leaves, fifteen tarnate flowers, and five lubilubi seeds using a mortar and pestle. The extracts were collected and placed in separate containers to be tested (Figure 1).

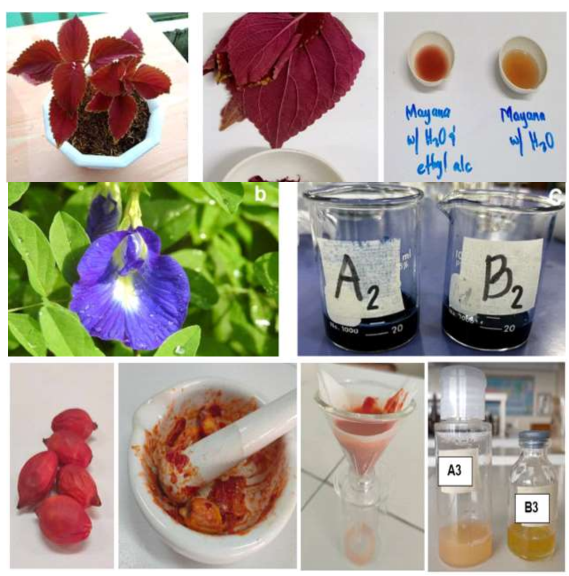

Figure 1. First row: *C. blumei* leaves and extracts; Middle row: *C. ternatea* flowers and extracts; Last row: *A. catechu* seeds and extracts

About 5 mL of the natural indicators were added into the solution with pH 1, pH 7, and pH 13 to determine the available colors in acidic, neutral, and basic substances. The same procedure was repeated to pH 2-6 and 8-12, and color changes were observed. The indicators were then tested for common household substances (orange juice, vinegar, soft drink, muriatic acid, feminine wash, baking soda, ethyl alcohol, liquid soap, liquid sosa [drain cleaner], and bleach) to see if they can give the same pH characteristics or pH values as indicated in the household product label.

The nature, goals, advantages, and risks of the study and teachers' voluntary participation were determined before their assent. The teachers then made the standard solutions at home using readily available household apparatus while testing the indicators at school using laboratory glassware. They were split into three groups for the experiment: Group 1, who worked on mayana leaves; Group 2 on ternatea flowers; and Group 3 on lubilubi fruits. They followed the instructions, noted the observations, and documented the outcomes with photographs (Figure 2).

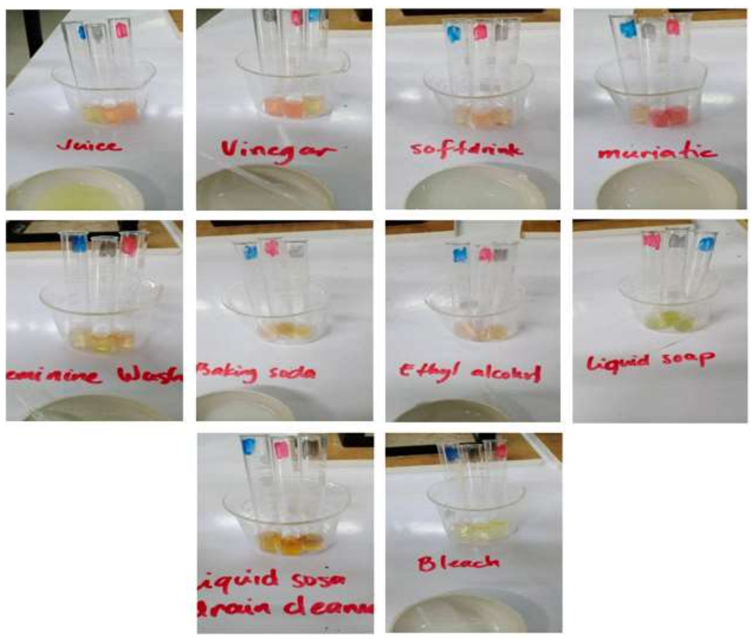

Figure 2. Household chemicals with natural acid-base indicators. Label: blue=*C. blumei*, gray=*C. ternatea*, pink=*A. catechu*

Afterward, the teachers responded to a validated Likert-scale questionnaire about the experiment's viability and satisfaction with it, considering the abilities of their students when they conducted it. Also the teachers were subjected to an unstructured interview, gathering data about their experiences while conducting the experiments at home and school.

Instrument

There were two research instruments used in this study. The first instrument was a validated Likert-scale questionnaire adapted from the study of Sanchez et al. (2021). The variables included in the questionnaire were based on the factors stated by Neves et al. (2017) and Andrews et al. (2020). The said instrument has five variables, namely independent learning, IL (9 items), resource availability, RA (8 items), adult supervision, AS (9 items), safety considerations, SC (9 items), and satisfaction (11 items). Pilot testing was conducted to establish the validity and reliability of the instrument. The testing yielded Cronbach alpha values of 0.95 for IL, 0.86 for RA, 0.98 for AS, 0.91 for SC, and 0.93 for satisfaction. These alpha values mean that the tool has good-to-excellent reliability; therefore, the tool was applicable to the study context.

The second tool was an interview guide. This guide has four main questions that center on opportunities, experiences, difficulties faced, steps to overcome these difficulties, and recommendations for teaching. There were also probing questions to follow up on the main queries. Experts in the field validated these questions.

Data Analysis

The collected data were organized and managed in Microsoft Excel and analyzed using the Statistical Package for Social Sciences (SPSS). The levels of feasibility and satisfaction were analyzed through descriptive statistics, mainly through means and standard deviations. The relationship between the abovementioned variables was tested through the non-parametric Spearman rho statistics at a 95% confidence level. Lastly, the qualitative data were analyzed through Braun and Clarke's (2006) thematic analysis with six steps to generate the themes of the study.

■ RESULTS AND DISCUSSION

Feasibility of the Home-based Experiments

The results of the evaluation of teachers on the feasibility of the home-based experiments are presented in Table 1.

Table 1. Feasibility of the home-based experiments

Aspect	Mean	SD	Description[1,2]
Independent Learning (IL)	4.52	0.50	Very feasible
Resource Availability (RA)	4.25	0.43	Very feasible
Adult Supervision (AS)	2.48	1.06	Feasible
Safety Considerations (SC)	4.28	0.68	Very feasible

[1]For independent learning, resource availability, safety consideration: 1.00-1.80 (Not feasible), 1.81-2.60 (Fairly feasible), 2.61-3.40 (Moderately feasible), 3.41-4.20 (Feasible), 4.21-5.00 (Very feasible)

[2]Reverse scoring for adult supervision: 1.00-1.80 (Very feasible), 1.81-2.60 (Feasible), 2.61-3.40 (Moderately feasible), 3.41-4.20 (Fairly feasible), 4.21-5.00 (Not feasible)

As shown in Table 1, the independent learning aspect (ì=4.52) makes the home-based experiment very feasible, indicating that students could practice independent learning in the experiment. At the same time, they learned through the experiment on their own. This finding shows home-based experiments as a critical aspect in fostering a sense of responsibility, initiative, and willingness to perform the experiments by the students, which are few indicators of independent learning (Bishop et al., 2021; Sanchez et al., 2021). Through home-based experiments, students can learn by themselves as they observe and relate to concepts discussed in the class (Mojica & Upmacis, 2022). Skills in scientific thinking and inquiry are improved (Sanchez, 2018; Sanchez, 2021; Velarde et al., 2022).

Resource availability (ì=4.25) and safety considerations (ì=4.28) also made the experiment very feasible, indicating that the resources are easy to find and readily available at home while maintaining a safe working environment for the students. These two aspects are per the recommended principles of designing home-based experiments. Lab materials should be accessible at home or in the community, such as supermarkets and pharmacies (Caruana et al., 2020; Santiago et al., 2022). Experiments should present no safety issues at home using safe household items and require no special equipment while delivering a genuine chemistry laboratory experience (Andrews et al., 2020). Blended chemistry materials, including lab manuals, should include safety and proper handling of materials (Chans et al., 2022).

However, the experiment is only feasible when it comes to adult supervision (ì=2.48), signifying that students still need the guidance of an adult when experimenting. According to Robledo (2021), although home-based experiments promote independent learning, students should perform the experiments under the supervision of their parents and guardians.

Satisfaction Level towards the Home-based Experiments

The results of teachers' evaluation of the satisfaction level with the home-based experiments are presented in Table 2.

Table 2. Satisfaction towards the home-based experiments

Indicators	Mean	SD	Description[1,2]
My interest and curiosity sparked upon scanning the lab activity.	4.89	0.32	Strongly agree
I had fun and enjoyed doing the experiment.	4.89	0.32	Strongly agree
The lab report is manageable to make.	4.89	0.32	Strongly agree
My laboratory skills are used in this activity.	4.78	0.42	Strongly agree
The experiment is safe.	4.78	0.42	Strongly agree
I learned about acid-base indicators because of the experiment.	4.67	0.48	Strongly agree
The worksheet is easy to understand and answer.	4.67	0.48	Strongly agree
The discussion and post-lab questions are easy because these are based on the results.	4.67	0.67	Strongly agree
The materials and equipment are easily found at home and in the community.	4.56	0.69	Strongly agree
The procedure is easy to understand and do.	4.56	0.69	Strongly agree
I require less supervision from adults when doing the experiment.	4.56	0.69	Strongly agree
Overall Satisfaction	4.72	0.40	Very satisfactory

[1]For individual indicators: 1.00-1.80 (Not satisfactory), 1.81-2.60 (Fairly satisfactory), 2.61-3.4 (Moderately satisfactory), 3.41-4.20 (Satisfactory), 4.21-5.00 (Very satisfactory)
[2]For Overall satisfactory level: 1.00-1.80 (Not satisfactory), 1.81-2.60 (Fairly satisfactory), 2.61-3.4 (Moderately satisfactory), 3.41-4.20 (Satisfactory), 4.21-5.00 (Very satisfactory)

Based on Table 2, the individual indicators (range ì = 4.56 - 4.89) proved that the participants were highly satisfied with the home-based experiment. The evaluation of teachers, considering the situation of the students, on the experiment gave a very strong affirmation of interest-prompt (ì=4.89) and enjoyment (ì=4.89) of the experiment as well as its lab report-workability (ì=4.89). Curiosity and interest increase when hands-on activities, including experiments, are implemented (Kibga et al., 2021).

The participants learned the acid-base indicators because of the experiment (ì=4.67), while laboratory skills were put into practice (ì=4.78) considering the prime safety of the conduct (ì=4.78). Implementing chemistry experiments provides opportunities for observing chemical phenomena and relating them to the concepts discussed (Mojica & Upmacis, 2022; Velarde et al., 2022). Aside from this, safety is crucial to experimentation, and considering this safety makes the home-based experiments very satisfactory (Andrews et al., 2020; Chans et al., 2022).

As found, the participants also strongly agreed on the ease of answering the worksheet (ì=4.67), the discussion, and post-lab questions (ì=4.67) feasibly because the experiment is deemed material-accessible (ì=4.56) and has a comprehensible procedure (ì=4.56) thereby found as requiring less supervision (ì=4.56). These individual indicators substantiate the overall satisfaction level of the participants as very satisfactory (ì=4.72). Chemistry experiments, including home-based experiments, are crucial to chemistry blended instruction, paving the way for high satisfaction among students and teachers (Sanchez, 2017; Redhana et al., 2019; Sanchez et al., 2021).

Association between Feasibility and Satisfaction

The association between different aspects of feasibility and satisfaction with home-based experiments is summarized in Table 3.

Table 3. Relationship between feasibility and satisfaction level towards the experiment

Variable Pairs	Spearman rho	p-value	Interpretation[1]
IL and Satisfaction	0.255	.084	Not significant
RA and Satisfaction	0.574	.000	Significant
AS and Satisfaction	-0.118	.429	Not significant
SC and Satisfaction	0.415	.004	Significant

[1]Significant if p<.01; Not significant if p>.01

Table 3 shows that feasibility regarding resource availability (ñ=0.574, p=0.000) and safety considerations (ñ=0.415, p=0.004) significantly correlate with satisfaction with the experiment. The availability of the resources encourages students' resourcefulness and creativity, which will significantly affect their satisfaction with the experiment. Availability and contextualization of materials lead to satisfaction and enhanced student performance (Rivera & Sanchez, 2020; Picardal & Sanchez, 2022). Teachers also believed that when safety concerns are properly addressed, students will be predisposed to home-based experiments. Safety considerations make the home a secure and safe lab workplace, and students can effectively engage in home-based activities (Owolabi et al.,)

In contrast, independent learning (ñ=0.255, p=0.084) and adult supervision (ñ=-118, p=0.429) did not provide any relationship with satisfaction. This result means that learning by themselves and being supervised by their parents do not relate to their satisfaction with the experiment. Velarde (2022) had varying levels of understanding of home-based experiments that could be attributed to non-relationship with satisfaction. Independent learning and adult supervision may not be a significant correlate due to other factors that hamper the learning of students by themselves, such as difficulties, frustrations, inconsistencies, and inadequate communication between students and their parents or guardians (Bishop et al., 2021; Mojica & Upmacis, 2022).

Opportunities and Challenges conducting the Home-based Experiments

The participants experienced opportunities for blended learning while they conducted the home-based experiments. One participant shared,

"Since I am not in school, I need to get the materials at home. Because of this, I become creative in experimenting as I also become resourceful in getting *materials."* (Participant 3)

They could unleash their creativity and resourcefulness as they found available materials at home and in their community as alternatives to the materials found in the laboratory. With that, they could save up on expenses because the materials needed for the experiments are readily available and found at home. Aside from this, they acquired knowledge and skills about acid-base indicators based on their observations and findings from the experiment and appreciated the validity of Chemistry at home. Lastly, they were allowed to apply their knowledge and skills at home and make Chemistry enjoyable using household materials (Caruana et al., 2020; Rivera & Sanchez, 2020; Santiago et al., 2022).

The participants also experienced challenges in blended learning while conducting the home-based experiments. Two participants shared,

"Because I was performing the experiments at home, it was difficult to do everything independently. It was time-consuming because of all the preparations and the long experiment. I had no well-calibrated laboratory apparatus for measuring the acid and base solutions. Not to mention, our kitchen space was too small." (Participant 8)

"The experiments were fascinating and doable at home. I could differentiate acids and bases using natural indicators, but I think the measurements would have been better and more reliable if I had the appropriate tools. The plants were easy to find, but the equipment was challenging. It was also difficult to differentiate one color from another because the changes were faint." (Participant 4)

Common challenges include the availability of material and human resources, time management, safety, and accuracy of the measurements (Neves et al., 2017; Andrews et al., 2020). However, the participants were also able to address these challenges by being creative and resourceful with the materials they have at home and in their neighborhood, and by asking for assistance from any human resource at home. One teacher shared,

"Even though I am a teacher, I still asked my siblings and parents to help me with the experiment, especially in confirming my observations on the color changes. I had to ask for a 'second opinion' so that my data would be more reliable. Moreover, because I do not have any laboratory measuring apparatus, I used our measuring tools for baking instead." (Participant 5)

The participants recommend using local materials found at home in doing the experiments. Ensure that the procedure is applicable, easy, and can be done with less supervision from adults and emphasize safety protocols, use of protective gear, and proper disposal of waste (Chans et al., 2022). Another teacher shared,

"We should not forget that we are not doing the activity in the laboratory; thus we should experiment in a well-ventilated area to avoid suffocation." (Participant 6)

■ CONCLUSIONS

As conducted and evaluated by teachers, the home-based experiments on natural acid-base indicators are very feasible and highly satisfactory. Hence, the possibility of conducting this laboratory at home is a helpful learning experience for blended learning, which aims to foster the competencies and skills of the students in the laboratory while also illustrating the same acid-base chemistry principle as in a face-to-face setup.

The study has important implications for the teaching of science. Students can conduct experiments at home under the supervision of their guardians or parents; hence, home-school collaboration must be strengthened. Through the home-based experiments, the students can exercise their independence and resourcefulness as they find helpful materials for their experiments. They can also search for common plants in the community that can be used to indicate the acid-base nature of household materials. However, the study is limited to teachers conducting home-based experiments on acid-base indicators. The researchers recommend further experimental or quasi-experimental studies to establish home-based experiments as evidence-based practice in science teaching by triangulating the experimental results with qualitative experiences of the students and teachers and documentary analysis of the steps they followed throughout the experimentation.

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