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Acceptability of Smartphone-Based Color Detector for the Microscale Antioxidant Experiment for Junior High School Students

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Abstract

Aim: Colorimetric analysis is a widely used technique to determine the concentration by measuring the color change resulting from a chemical reaction. However, the conventional methods often require specialized laboratory equipment, rendering them inaccessible to schools and institutions with limited resources.
Methodology: In this study, 50 Junior High School students assessed the developed smartphone-based colorimetric experiment in terms of student engagement, clarity of the instruction, safety, and applicability of the developed materials in conducting chemistry experiment.
Result: Result of the investigation showed that the students had positive perception on the applicability of smartphone-based colorimetric antioxidant experiment.
Conclusion: The antioxidant content of Banaba tea sample as measured by each group using the smartphone colorimeters revealed is not statistically different from the value calculated using the standard colorimetric methods.

Keywords: antioxidant, clarity of instruction, students engagement, safety, colorimetric experiment

INTRODUCTION

The introduction of classroom experiments in the usual science teaching serves as a good starting point for problem discussion. It also enhances the interaction between the teacher and their students (Momanyi & Del Mundo, 2022). It helps students understand the theoretical concepts after the discussion of the experiments (Hart et al., 2000). Science is a very challenging and complex topic for most Filipino students. This complex and challenging nature of science is often reflected in the achievement test administered every year, and most of the time, science usually occurs at the lowest rank. As shown in the result of the Program for International Student Assessment (PISA) in 2018, the Philippines ranked 357th in science, which is below average compared to other participating OECD countries. This is probably because science as a subject requires prior knowledge of abstract and complex concepts. One of the best methods to address this problem is through collaboration and co-construction of knowledge and ideas in the educational practices (Amihan & Sanchez, 2023; Carvajal & Sanchez, 2023; Carvajal, Sanchez & Amihan, 2023; Khoo & Otrel-Cass, 2017; Sanchez, 2023a; Twum, 2017). If the students are allowed to perform activity-based learning, it makes the subject matter more comprehensible; students can easily remember the concepts, which leads to a more effective transfer of information and acquire favorable attitudes towards learning in general (Aladejana & Aderibigbe, 2007)

Science educators have emphasized the "discovery learning" by which students are given experimental materials and are expected to discover scientific principles independently. As suggested by Jean Piaget, children learn more if they understand the concept on their own. The idea of Piaget was then supported by John Dewey when he mentioned that students must be motivated with hands-on and real-world problems. Practical works such as laboratory experiments encourage students to learn by enhancing their observation and scientific skills and widen their way of thinking (Chebii et al., 2012; Inayah et al., 2020); on a practical side, performing laboratory experiments

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enable students to change theories into real-life applications, promote students interest in learning science, and, foster logical and reasoning skills (Shana & Abulibdeh, 2020)

One of the sought-after technological device that shows promising applications in science experiment is the smartphone. Smartphone application in chemistry classrooms has gained much popularity since almost all students can access smartphones. In a report from statistica.com, it was indicated that about 82.33 % of the population had access to a smartphone, and it was projected to increase to almost 90.04% at the end of 2025 (Martha Jean Sanchez, 2021)With this booming number of smartphone users, there is no doubt that the smartphone is genuinely an indispensable item. Hence, the possibility of it being used as part of a chemistry laboratory must be explored. The application of smartphones in the teaching and learning process has been shown to enhance students' learning and allows them to interact with their peers (Zedadra et al., 2019). Despite these, most primary and secondary schools in the Philippines do not utilize smartphones in teaching science laboratories. A smartphone is currently being used to present documents, write notes, watch educational games, listen to audio recordings, view a picture, watch clips, and take photographs (Davidovitch & Yavich, 2018; Twum, 2017). Most educators still see computers and smartphones as unrelated devices, and they specifically view smartphones as an accessory. Nowadays, many students use smartphones to do their school requirements, such as research, but mostly, it is limited to web browsing.

Several studies confirm that the smartphone is not just a simple communication device; it is a device with a diverse function that can be used in conducting low-cost chemistry experiments. In the study of (Destino & Cunningham, 2020) they mentioned that by allowing students to do chemistry at home, they become creative, critical thinkers and have a wide range of problem-solving skills that may not be exercised in traditional laboratory settings. One of the commonly performed experiment by most secondary school students is the determination of antioxidant activity of various plant materials, however, the procedure itself is expensive and not all schools in the country have the capacity to conduct colorimetric experiments.

Research Questions

The study sought to determine the perceptions of Junior High School students of Elpidio Quirino High School on the use of smartphone as a tool for antioxidant experiment.

Specifically, it aimed to answer the following questions:

a. What is the level of students acceptability of the developed smartphone-based colorimetric experiments in terms of
   1. student engagement;
   2. clarity of the instruction;
   3. safety; and
   4. applicability of the developed smartphone-based experiment in teaching and learning chemistry?

b. Is the developed method comparable to the standard colorimetric procedure as evaluated by the students?

METHODOLOGY

Research Design

This study utilized a descriptive research design.

Population and Sampling

For the purpose of this study, a total of 50 students were purposively selected from the population of Grade 9 and 10 students of Elpidio Quirino High School. The selection was based on the following criteria: (1) the students are interested in participating in the 2023 Science Investigatory Project, and (2) students have interest in conducting science related research.

Pilot Testing

The questionnaire used in this study determined the acceptability of the respondents on the developed smartphone-based colorimetric experiment and the questionnaire was sent to 30 respondents for pilot testing.

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Instrument

The acceptability of the developed smartphone-based colorimetric laboratory experiments, selected science teachers will be given a 14-item, 5-point Likert scale question regarding their perceptions on the applicability of the smartphone-based colorimetric experiments in terms of student engagement, clarity of the instruction, safety, and applicability of the smartphone-based colorimetric methods in teaching and conducting chemistry experiments.

To evaluate respondents perceived applicability of the smartphone-based colorimetric experiments, the following system was used.

Scale	Range	Adjectival Description
5	4.21 – 5.00	Acceptable
4	3.41-4.20	Slightly Acceptable
3	2.61 – 3.40	Undecided
2	1.81 – 2.60	Slightly Unacceptable
1	1.0 – 1.80	Unacceptable

Table 1. Adjectival description for the teachers and students' evaluation of the developed smartphone-based experiment.

After making the necessary revisions based on the expert's feedback, the researcher administered the revised questionnaire to 30 Grade 8 students to assess its reliability as a measurement tool. The questionnaire's reliability was analyzed using JAMOVI Statistical Software to ensure that it consistently measures what it intends to measure and can be used again in similar settings.

Students Learning Goal

Banaba (Lagerstroemia speciosa) is a member of Family Lythraceae and well known for its medicinal purposes.

The main student learning goal was to calculate the total phenolic content of banaba tea using smartphone-based colorimeters. As a result of performing the experiment, it was expected that students:

- understand the basic principle of spectroscopy.
- describe the chemical principle involved in the reaction of Folin-Ciocalteu.
- perform a quantitative analysis using smartphone-based colorimetry.

In the proposed smartphone-based colorimetry, students were grouped into five (5). Each group received a laboratory kit containing a small volume of chemicals placed in an amber vial and one unit of light box. All participants were given a lecture on basic colorimetry before they were allowed to perform the experiments. At the end of the experiment, all groups presented their post laboratory report. To measure the respondent's perception on the use of the smartphone-based colorimeter, a 14-item, 5-point Likert Scale was provided to all respondents.

Data Collection

After the students performed the experiment, they will answer the The collected data were collected, tabulated and interpreted using the Data analysis tool of MS Excel®.

Treatment of Data

Desciptive statistical analysis was performed to evaluate the students acceptability on the smartphone-based colorimetric analysis for the determination of antioxidant content of Banaba.

Ethical Considarations

The researcher ensured that all research protocols involving ethics in research were complied with for the protection of all people and institutions involved in the conduct of the study.

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RESULTS and DISCUSSION

Table 2. Result of the reliability test for the test questionnaire

Cronbach's Alpha	No. of Items
0.925	14

The table above showed that Cronbach's alpha is 0.925. This value can best be interpreted following the Cronbach's alpha descriptors suggested by Taber (2018).

The questionnaire used in this study determined the acceptability of the respondents on the developed smartphone-based colorimetric experiment, and the four (4) part questionnaire was sent to 30 respondents for pilot testing. The reliability of the instrument was tested against different variables such as Student Engagement (α = 0.847), Clarity of the instruction (α = 0.848), Safety (α = 0.728), and Applicability of the developed material in conducting chemistry experiment (α = 0.850), and these were all found to be reliable (Table 2).

Table 3. Result of the Reliability Testing on the different variables.

Variable	Cronbach's Alpha	Interpretation
Student Engagement	0.847	Reliable
Clarity of the Instruction	0.848	Reliable
Safety	0.728	Relatively High
Applicability of the developed material in conducting chemistry experiment	0.850	Reliable
Overall Test	0.925	Excellent

A. Acceptability of the developed and validated smartphone-based colorimetric experiment.

The general acceptability of the developed and validated experiment protocol was evaluated based on students' engagement, clarity of the instruction, safety, and applicability of the developed material in teaching and conducting chemistry experiments.

Student Engagement

In the first criteria, the respondent's degree on agreement for the student engagement was assessed and the result is presented in the table below.

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Table 4. Summary of Responses for Student Engagement

Item Questions	Mean	Std. Dev.	Adjectival Interpretation
Question 1. The content of the developed smartphone-based chemistry experiment is suited for the students' level of development	4.80	.495	Acceptable
Question 2. The experiment presented is challenging, engaging and interesting	4.68	.551	Acceptable
Question 3. The experiment activity sparks the interest of the students	4.58	.609	Acceptable
Question 4. The experiment provides greater understanding of concepts for the students	4.72	.454	Acceptable
Question 5. The developed material is applicable to enhance students higher order cognitive skills such as problem solving, critical thinking, learning by doing etc.	4.78	.418	Acceptable

In the first question most, respondents agreed that the smartphone-based colorimetric experiment is well suited to the students' level of development (M = 4.80, SD = 0.495) this statement is confirmed with the low standard deviation suggesting that there is a low variability in the responses, indicating a consensus among the respondents. Majority of the respondents believed that the smartphone-based experiment is challenging, engaging and interesting (M = 4.68 , SD = 0.551), sparks their interest (M=4.58, SD=0.609), provide greater understanding of the colorimetry /spectrophotometry (M=4.72, SD=0.454), and enhance their higher order cognitive skills such as problem solving, critical thinking through learning by doing (M=4.78 , SD=0.418). The findings of this study agrees study published by (Kimbrough et al., 2017), wherein they've mentioned that majority of the students believed that smartphone promotes positive experience.

Clarity of the Instruction

Clear instructions help learners understand what they need to do and how to accomplish it, leading to better engagement and improved learning outcomes. In this study, the respondents evaluate the developed experiment sheet based on the attainability of the experiment objective and the clearness of the instruction (Table 5)

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Table 5. Summary of Responses for Clarity of the Instruction

Item Questions	Mean	Std. Dev.	Adjectival Interpretation
Question 6. The objective of the students' learning material is suited and attainable	4.52	.614	Acceptable
Question 7. Experimental procedure is clear, and free from technical error	4.68	.551	Acceptable

The majority of the respondents believed that the objectives of the students' learning material is suited and attainable (M=4.52, SD = .614) and the experimental procedure is clear and free from technical error (M=4.68, SD = .551). However, the slightly elevated standard deviation of both items suggests that there was some variability in the ratings. Result of the investigation shows that students viewed the developed instructional materials to be clear and can easily be understood.

Safety of the Students in while conducting the experiment

To safeguard the health of those doing the experiment, the safety of laboratory operations in an experiment sheet is essential. It is imperative that the safety of all the students performing the experiments must be taken care of and all safety precautions must be thoroughly discussed, itemized and reiterated to the development of experiment sheet (Table 6).

Table 6. Summary of the Responses for Safety

Item Questions	Mean	Std. Dev.	Adjectival Interpretation
Question 8. All procedures in the experiment possess minimal error and can be safely performed by the students	4.64	.563	Acceptable
Question 9. Safety precautions were included in the developed smartphone-based experiment sheet and can easily be understood by the students	4.54	.613	Acceptable

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The responses of the participants regarding their perceived safety of the proposed experiment showed that the experimental procedures were designed with minimal errors and found to be safe for students to perform (M= 4.64, SD = .563). At the same time, most of the respondent believed that the developed smartphone-based colorimetric experiments sheet included a clear and precise instruction on the precautions that students need to undertake prior to the induction of the experiment (M=4.54, SD = .631)

Applicability of the developed materials in conducting chemistry experiments.

The positive perception of the respondents on the applicability of the developed material in conducting chemistry experiments was highly reflected in the average (Table 5). In the first statement, most of the participants believed that the validated instructional materials accurately explained and presented a complex concept such as colorimetry without any conceptual error (M = 4.58, SD = .609) and the chemical information derived from this innovation is comparable to the standard colorimetric method (M = 4.70, SD = .505). The majority of the respondents believed that they easily understand the operation and technicality of the proposed method and that students can be performed by the students with minimal supervision (M = 4.65, SD = .525). The positive impact of using the smartphone as an alternative to the commercial colorimeter in chemistry experiments caught the interest of the students and therefore expressed their intention to use the smartphone-based colorimeter as part of their laboratory activities (M = 4.62, SD = .635) and would recommend the use of smartphone-based colorimeter to their peers (M = 4.70, SD = .678).

Table 7. Summary of the Reponses for the Applicability of the developed material in conducting chemistry experiments.

Item Questions	Mean	Std. Dev.	Adjectival Interpretation
Question 10. There are no conceptual errors, all chemical concepts are accurately explained and presented	4.58	.609	Acceptable
Question 11. The chemical information derived from smartphone-based colorimeter is comparable to the standard colorimetric method	4.70	.505	Acceptable
Question 12. The operation of the smartphone-based colorimeter is easy, and students can easily use this method without much supervision	4.64	.525	Acceptable
Question 13. I intend to use the smartphone-based colorimeter in my laboratory class	4.62	.635	Acceptable
Question 14. I would recommend the use of smartphone-based colorimeter to my classmate/and or research colleagues	4.70	.678	Acceptable

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The findings of this study showed that students accepted the utilization of smartphone-based colorimeters as a tool in antioxidant analysis. These agreed with the findings of previous researcher regarding the applicability and usability of smarhone in conducting chemical analysis ((Chanla, J., Kanna, M., Jakmunee, J., & Somnam, 2019; Chen et al., 2019; Huang, 2017; Kehoe & Penn, 2013).

B. Students Evaluation of the Antioxidant Activity of Banaba Tea using Smartphone-based colorimeter

The antioxidant activity of banaba tea leaves was evaluated among five groups of students using a smartphone-based colorimeter (Table 6). The results revealed variations in the antioxidant activity across the groups. Group 4 exhibited the highest antioxidant activity with a mean Gallic Acid Equivalent (GAE) of 0.6273 mg/g of banaba tea sample, followed by Group 2 with a GAE of 0.6146 mg/g of tea sample, Group 1 (GAE = 0.5687 mg/g), Group 5 (GAE = 0.5428 mg/g), and Group 3 (GAE = 0.5158). Although, group 4 measured a higher amount of GAE, statistical analysis using paired t-test indicated that there was no significant difference between the calculated GAE of Group 4 with the GAE measured by Group 1 [$t(4) = 0.171$, $p = 0.872$), Group 2 [$t(4) = 0.248$, $p = 0.816$], Group 3 [$t(4) = 0.439$, $p = 0.383$] and Group 5 [$t(4) = 0.439$, $p = 0.683$].

Table 8

Comparison Between the Calculated Gallic Acid Equivalent (GAE) of Five (5) Groups

	Group 1	Group 2	Group 3	Group 4	Group 5
Average Red Values	139.6	132.2	113	121.8	138.2
Average Absorbance	0.1541	0.1539	0.1540	0.1545	0.1584
GAE (mg/g)	0.5687	0.5416	0.5158	0.6273	0.5428
Standard Deviation	0.4763	0.1703	0.5116	0.6180	0.2624

Conclusion

Colorimetry can be used to analyze the concentration of an analyte by measuring its light transmission or absorption. Unfortunately, not all schools in the country are blessed enough to have their own colorimeters, hence the goal of this experiment. The experimental procotol presented in this study had been evaluated in terms of student engagement, clarity of the instruction, safety, and the applicability of the developed method in conducting chemistry experiments. The instructional material developed for this experiment was commended for its clarity, lack of technical errors, and achievable objectives. Respondents expressed confidence in the experimental procedure outlined in the proposed experiment sheet, ensuring the safety of students during the experiment. Following the completion of the hands-on smartphone-based colorimetric experiments, a majority of the respondents confirmed the absence of conceptual errors in the experiment protocol.

The proposed experiment, which utilized the validated smartphone-based colorimetric method, was deemed suitable for junior high school students. It aligned with their level of development, enhanced their understanding of chemical concepts, and promoted higher-order thinking skills. Additionally, the experiment was found to be challenging, engaging, and interesting.

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Lastly, smartphone-based colorimetric experiments offer a practical and convenient approach for students to learn about chemical analysis, particularly in educational settings where access to specialized laboratory equipment may be limited

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