RGB-ColorMeter on smartphones as a simple spectrophotometer: An alternative method of teaching spectrophotometry at the vocational high school of chemical analysts

M Paristiowati*, M Moersilah, M Nurjayadi and A N Fitria
Department of Chemistry Education, Faculty of Mathematics and Natural Science, Universitas Negeri Jakarta, Jakarta, Indonesia

*maria.paristiowati@unj.ac.id

Abstract. This study aims to improve students' understanding at the Vocational High School of Chemical Analysts on spectrophotometric concepts through experiments using smart phone technology. For this research, The ColorMeter application with matching red green blue (RGB) colors is used as a simple spectrophotometry. The use of smartphone as a simple spectrophotometry in practice can maximize spectrophotometric learning activities in the classroom since these are often constrained by the limited access to the instrument. Through finding an alternative method, learning objectives can be properly achieved and practical application is easily attained. This RGB – ColorMeter application can be used to read the transmittance of a colored solution by utilizing the complementary colors of the solution being tested. Transmittance data obtained is used to find the absorbance of the solution, so that it can determine the concentration of a substance in the solution. The results showed that the application of RGB-ColorMeter can show a linear graph between concentration and absorbance. The whole process is then carried out individually by each student starting from the stages of designing, utilizing, and reviewing this simple spectrophotometer. Students' understanding of spectrophotometric concepts increases because each student follows the process thoroughly from the beginning to the final stages of the spectrophotometry practicum. Thus, it can be deduced that the application of RGB-ColorMeter can be used as a simple and accessible spectrophotometer in the spectrophotometry practicum at the Vocational High School of Chemical Analysts.

1. Introduction
Spectroscopy is the study of determining the number of compounds contained in a sample by accurately measuring the amount of light absorbed or emitted by the atoms or molecules contained in that sample [1]. In line with that, determining the concentration of analyses means of spectrophotometry through applying the Lambert-Beer Law is an important concept that must be mastered by students in learning chemistry. However, given the limited resources and facilities in many high schools and colleges, it is not surprising that some researchers are looking for ways to make a simple spectrophotometer, a prototype that can be designed, made, and used by every student to learn more on spectrophotometry.

Spectrophotometric instruments actually have a simple design, but the components required are quite many because it requires the use of light-emitting diodes, photodiode detectors, and the like [2]. In order
to make these instruments accessible for all students which should then make learning more effective, the components can be simplified by utilizing cellular phone cameras as spectrophotometric analysts [3]. The experiments presented here have enabled students to conduct Lambert-Beer Legal Analysis by actually using their cellular phone’s camera through the use of an application called ColorMeter. ColorMeter is a valuable camera instrument that permits you to pick live colors around you using a smartphone. It shows RGB components of the color and display it on the screen. The hexadecimal (HTML) color code used in graphic, picture or photo editors is also displayed. Experiments carried out with a simple spectrophotometer are a simple way to help students explore the concept of spectrophotometry with equipment that is easily found in their high school chemistry laboratories [4].

The experimental process allows students to explore concepts both quantitatively and qualitatively. Moreover, there are other forms of media that could be used as an alternative. Simple spectrophotometers can also be made using card boards, DVDs, digital cameras, tripods, and computers that have been studied and tested [5]. On the other hand, a simple spectrophotometer, a mobile-based spectrophotometer has been optimized as an instrument for teaching the basic concept of spectrophotometry which is the application and observation of the Lambert-Beer Law [6].

The advantage of a simple spectrophotometer is that it is easy to make and inexpensive which paves the way for more practical activities. Hands-on activities can be done by utilizing gadgets that are commonly used every day, and with other equipment and tools that are easy to find and easy to assemble [7]. It is important to note that conducting hands-on activity provides students with an experiment to discover concepts directly through their own experience and construct their own understanding especially when it comes to abstract ideas or concepts that could not be easily observed with the naked eye such as spectroscopy. Hence, this spectrophotometric design encourages students to interact directly with the components so there are more probabilities for students to be engaged and test the theory they have learned in class [4]. It is also expected to increase the learning motivation of students who tend to learn visually as they are in the era of the Industrial Revolution 4.0 since technology opens the door for additional research into the impact of technology on student motivation for learning [8]. This research will help students understand the Lambert-Beer concept more straightforwardly in a more comprehensive manner. This experiment also aims to yield good results so that it can be used by chemistry teachers who want to convey spectrophotometric learning with limited tools and funds.

2. Methods
This paper characterizes the usage of technology, which is ColorMeter, as an alternative method of teaching spectrophotometry. This research was conducted at the Vocational High School of Chemical Analysts where spectrophotometry concept is rigorously learned by the students by doing a practicum. The practicum conducted by determining the levels of Nitrite (NO\textsubscript{2}) in solutions containing Nitrite (NO\textsubscript{2}) with a simple spectrophotometer. Determining the nitrite ions is based on the reaction of diazotization with sulfanilamide (4-aminobenzenasulfonamide) reagents-compounds resulting from the reaction formed with N-(1-naphthyl)-ethylenediamine dihydrochloride (coupling reaction). Various methods in the fields of pharmacy, chemistry, and even bacteriology have been developed based on the diazotation-coupling reaction among them is detection of nitrate as a reduction of nitrate by bacteria, determination of the Furosemide levels, documentation of the nitrite levels in water, and others [9]. In this study, students are expected to do the practicum individually and independently. Students have to be actively involved from the beginning until the end of the process, starting from materials and tools preparation until the calibration curve interpretation that will be done by the end of the practicum. The whole process of the practicum covers the steps during preparation, utilization, and recapitulation as shown in Figure 1.
3. Results and discussion

3.1. Simple spectrophotometer design results
Here are the results of a simple spectrophotometer design. Simple spectrophotometer components consist of a photo background, a box of food packaging, transparent plastic cups, and the ColorMeter application that is installed in the smartphone which can be seen in Figure 2.

The color of the background used is the complementary color of the solution’s color. The color of the solution containing nitrites is reddish-pink, so the background used is green [10]. The α-naphthylamine compound was first used by Peter Griess in 1879 as a coupling compound with a diazonium salt source sulfanylic acid to detect the presence of nitrite in a solution or mixture. The reddish color formation of Azo complex compounds occurs when NO₂ reacts with sulfanylic acid and N-(1-Naphthyl Ethylene
Diamin Hydrochloride) at pH 2.0-2.5 [11]. The background color that is green shows that the G value (green) can be detected in the smartphone screen. The G value indicates intensity of the light that can travel through the solutions. Figure 4 shows the results of reading the RGB value in the ColorMeter application.

![Image](image_url)

**Figure 3.** Reading of RGB values using the application.

### 3.2. Spectrophotometer test results with nitrite solution

Spectrophotometer testing is done by testing the blank solution, standard series solution 1 to standard series solution 5 with concentrations of 0.02 ppm, 0.04ppm, 0.06 ppm, 0.08 ppm, and 0.1 ppm, and duplo sample solutions. Through this test, the G value indicates that the higher the concentration of the solution, the G value will decrease. In optics, that portion of physics that deals with the properties of light, the measurement of the number of photons delivered at a point in a given unit of time is called the Intensity, I. Higher intensity could be thought of as "brighter" and lower intensity could be thought of as "dimmer"; hence high-intensity light will be bright and low intensity light will be dim [12]. After the G value is obtained, the percentage of transmittance and absorbance value can be found. Table 1 shows the tendency of G value, percent transmittance, and absorbance towards concentration.

**Table 1.** Simple spectrophotometer trial results.

| Concentration (ppm) | G Value | Transmittance (%) | Absorbance   |
|---------------------|---------|-------------------|--------------|
| Blanko              | 0       | 139               | 100          | 0            |
| Standard 1          | 0.02    | 98                | 70.50        | 0.1518       |
| Standard 2          | 0.04    | 58                | 41.72        | 0.3796       |
| Standard 3          | 0.06    | 45                | 32.37        | 0.4898       |
| Standard 4          | 0.08    | 35                | 25.17        | 0.5991       |
| Standard 5          | 0.10    | 23                | 16.54        | 0.7814       |

Using the results from Table 1, a calibration curve can be made in order to analyze the relationship between concentration and absorbance. The calibration curve shows that the higher the concentration, the higher the absorbance value. Calibration curves from the results of a simple spectrophotometer test can be seen in Figure 4.
Figure 4. A calibration curve for the results of a simple spectrophotometer test.

3.3. Analysis of the relationship between concentration and transmittance and absorbance
Table 1 shows the relationship between the concentration of the solution and the intensity of the light passing through the complex solution which is read by the ColorMeter application. The test results show the greater the concentration of the solution, then the intensity of the light that is successfully passed through the complex solution will decrease, so the value of $G$ that is read in the application also decreases. This is caused by the absorption of light by particles contained in complex solutions. Furthermore, the value of $G$ which is the value of light intensity also shows a relationship with transmittance. The smaller the value of $G$, the percentage of transmittance will increase. The test results also reveal that as the percentage of transmittance decreases, the absorbance value increases.

By analyzing all of the data presented, it can be concluded that the results of this study indicate the greater the concentration of solution, the percentage of transmittance will decrease. Meanwhile, if the concentration of the solution gets bigger, the absorbance value will increase. The results of this study are in accordance with Lambert-Beer Law. The Beer-Lambert law states that the quantity of light absorbed by a substance dissolved in a fully transmitting solvent is directly proportional to the concentration of the substance and the path length of the light through the solution.

The results indicated that the use of RGB - ColorMeter can show a linear graph between concentration and absorbance. The entire procedure is then completed independently by each student starting from the stages of designing, utilizing, and reviewing this simple spectrophotometer. Students' comprehension of spectrophotometry concepts increases because each student follows the procedures completely from the beginning to the final stages of the spectrophotometry practicum.

4. Conclusion
It can be concluded that the RGB-ColorMeter application can be used as a tool for a simple and accessible spectrophotometer in the spectrophotometry practicum. The use of the RGB application can be an alternative way for learning spectrophotometry at the Vocational High School of Chemical Analysts. Research shows that this learning alternative makes students more motivated by learning transmittance and absorbance since they were able to experience it directly by using gadgets that they use on a daily basis. Students were deeply engaged from the initial stages of making a simple spectrophotometer to applying the Lambert-Beer concept in studying spectrophotometry. With this, it can also be said that in spite of the challenge often posed when studying Chemistry, it is necessary to provide a rich learning environment for students to develop such skills that includes contextual relevance, and opportunities for practice, discussion and feedback. The challenge of this study was encouraging students to find a constant lightning because this study used sunlight as the lightning source.
Acknowledgments
We would like to express our sincere gratitude to Ministry of Research, Technology, and Higher Education Indonesia for the grant, Universitas Negeri Jakarta, and Tunas Harapan Vocational High School of Chemical Analysts for the tremendous support.

References
[1] Cairns D 2012 Essentials of pharmaceutical chemistry (Pharmaceutical Press)
[2] Grasse E K 2015 Creation of a portable, 3D-printable, iPhone-compatible spectrophotometer
[3] Scheeline A 2017 How to design a spectrometer Applied spectroscopy 71 10 2237-2252
[4] Kuntzeeman T S and Jacobson E C 2016 Teaching Beer’s law and absorption spectrophotometry with a smart phone: a substantially simplified protocol Journal of Chemical Education 93 7 1249-1252
[5] Widiatmoko E, Budiman M and Abdullah M 2011 A simple spectrophotometer using common materials and a digital camera Physics Education 46 3 332
[6] Grasse E K, Torcasio M H and Smith A W 2016 Teaching UV–Vis spectroscopy with a 3D-printable smartphone spectrophotometer Journal of Chemical Education 93 1 146-151
[7] Manurung S R and Panggabean D 2017 Analysis of Learning Tools in the study of Developmental of Interactive Multimedia Based Physic Learning Charged in Problem Solving Journal of Physics 846 2017
[8] Hew K F and Brush T 2007 Integrating technology into K-12 teaching and learning: Current knowledge gaps and recommendations for future research Educational technology research and development 55 3 223-252
[9] Metwally M E S and Belal F F 1992 Primaquine Phosphate as a Promising Substitute for N-(1-Naphthyl) ethylenediamine I. Determination of Nitrite in Natural Waters in Egypt Analytical sciences 8 1 71-75
[10] Babič V and Čepič M 2009 Complementary colours for a physicist. European journal of physics 30 4 793
[11] Pavlidis V H 1990 Organic chemistry (California: Brooks/Cole)
[12] Hardesty J H and Attili B 2010 Spectrophotometry and the Beer-Lambert Law: An Important Analytical Technique in Chemistry (Collin College, Department of Chemistry)