# DEVELOPMENT OF A COLORIMETRIC MEASUREMENT MOBILE APP FOR ACTIVE LEARNING IN ANALYTICAL CHEMISTRY

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**ABSTRACT**

This paper describes the development of a mobile application to engage students in active learning in analytical chemistry. Colorimetry is a topic in analytical chemistry that can effectively be learned through the use of mobile devices to perform colorimetric measurement in the real-life environment. Previous attempts in the development of colorimetry mobile apps have been described in the literatures, however, shortcomings exist in their ease of use for teaching and learning and dissemination. We herein propose a colorimetry mobile app design that allows anyone to download, and easily perform colorimetric measurements and engage in active learning anytime, anywhere. Pedagogical underpinnings of the mobile learning activity and app design will also be discussed.

**KEYWORDS**

Active Learning, Informal Learning, Experiential Learning, Chemical Education, STEM

## 1. INTRODUCTION

Today's learners are always on the move, and a great deal of learning happens outside the classroom (Sharples et al., 2005). With mobile devices, students can acquire knowledge anytime, anywhere, achieving ubiquitous learning outside the classroom walls. Mobile learning can thus be perceived as a "natural" way of learning, as suggested by Low and O'Connell (2006): "learning has always been mobile: we all learn as we go about our lives, with inherent dynamism and personal mobility." In science education, Zydney (2016) also notes that "much of science takes place outside of the classroom and is arguably better studied in its natural environment", and she postulates that "science learning are well aligned with the mobility of newer devices as well as their ability to display interactive, three-dimensional graphics and simulations." On the other hand, active learning in science-related subjects and respective benefits are extensively researched and described in the literatures (de Caprariis, 2012; Freeman, 2014; Kontra, 2015). Therefore, rather than passively learning in the confines of a classroom, students can acquire scientific concepts more effectively through the use of mobile devices through active learning in the real-life environment.

The current study focuses on active learning in analytical chemistry, which is the study of instruments and methods applied to separate, identify and quantify matters. Colorimetry is a technique in analytical chemistry for the quantitative determination of colored compounds in a solution. For example, colorimetry can be used to measure the concentration of heavy metals, sugars, proteins, food preservatives, environmental pollutants and other molecules in sample solutions. Colorimetric measurement is typically performed by the UV-visible spectrophotometer, which could cost up to USD50,000; this may not be worthy for some school laboratories. Yet, colorimetric measurement is a common topic in chemical education, and its practical applications can be valuable for anyone to learn and apply in daily life. Therefore, a colorimetric measurement mobile app that is fully functional on common mobile devices is an ideal tool for chemistry students to perform active learning in the real-life environment.

## 2. MOBILE APP DEVELOPMENT

As the affordability of mobile devices and the quality of their built-in cameras continually increase, the use of mobile devices for colorimetric measurement has been explored in various studies (Kehoe, 2013; Campos, 2015; Koesdjojo, 2015; Knutson, 2015). The general workflow described in these studies are as follows: use the mobile phone's native camera app to take color images of the sample solution, and use a general-purpose color-picker app or desktop software to extract the RGB (Red-Green-Blue) values in the images. Then, use a spreadsheet app or desktop software (e.g. Excel, Google Sheets) to tabulate the RGB values, and compute the absorbance, calibration profile and concentration of the sample solution. These studies use a combination of different apps and/or software on multiple platforms to complete the different steps in the workflow of colorimetric measurement, which may be inconvenient to the users, and may lead to erroneous results due to human errors when copying data from one software or platform to another. Lopez-Ruiz (2014) and Hussain (2016) studies attempted to create a single mobile app that integrates the different steps of the measurement workflow. However, their apps were designed specifically to function within the context of their studies and publications (i.e., pH value, nitrite content, and fluoride content), and their user-interfaces were not designed to cater for a general audience with no prior knowledge in colorimetry. Furthermore, the app by Hussain (2016) require a special device to fixate the sample solutions in front of the mobile phone camera lens, limiting both portability and practicality. Moreover, at the time of this writing, both apps were only compatible with Android mobile devices, and were not made publicly available on Google Play store.

### 2.1 App Design & Usage

The current study will design and produce a mobile app (tentatively named "SPECTRAL") which will be compatible for both Android and Apple iOS mobile devices, and made freely available on Google Play and Apple App Store. The app will allow anyone with a mobile device to perform colorimetric measurement using the built-in camera at anytime, anywhere without any external apparatus. Our mobile app will consist of two modes of operation: calibration and measurement modes. In calibration mode, the phone's built-in camera will capture color image of standard solution placed in front of the mobile phone. This image capturing is repeated several times for the same type of standard solution of different known concentrations and the RGB values of these images are automatically extracted and stored with the respective concentration values (input by the users). These values will be used to calculate the absorbance and construct a calibration profile. The absorbance obtained is a normalized value which is dependent of the concentration of sample solution (provided that the optical path is fixed). Once the sample container is the same as that of standards used for calibration, the quantification would be accurate. In measurement mode, the user uses the app to capture a color image of sample solution of unknown concentration, and based on the calibration profile of the same type of solution previously measured in calibration mode, the app will compute and output the extrapolated concentration of this solution.

The app's user-interface design will employ on-demand tooltips, so that instructions will be revealed just-in-time as user progresses through the measurement workflow. Another important feature of the mobile app design will be its support for informal learning experience. Active learning in the real-life environment may not necessary occur within the context of a formal learning experience led by an instructor. Informal learning using mobile apps usually occurs during out-of-school time, which means users can be with highly varied age, interest, background, and prior knowledge (Land, 2015). In light of this, when designing the app, self-guided instructional material on the topic of colorimetry will be strategically embedded into the measurement workflow, so that users who have no prior knowledge can also use the mobile app to informally learn and apply colorimetric measurement in the real-life environment.

The completed app will eventually be applied in undergraduate level chemistry, integrated science and general education courses at the Hong Kong Baptist University and other sister institutions in Hong Kong. It will first be introduced to students in formal learning settings: during laboratory classes when pre-designed laboratory experiments involving colorimetric measurement takes place, and during project-based learning experience, such as field trips and undergraduate final-year projects, when students will use the app as an active learning and investigative tool to study a chemistry related problem. We are also partnering with the Hong Kong Education Bureau, which will introduce the mobile app to the Hong Kong secondary schools for promoting active learning in STEM (Science, Technology, Engineering and Mathematics) education.

It is expected that about 700 local Hong Kong secondary school students will be using this app each year for their study in chemistry.

As mentioned previously, the app will be designed to support active learning in an informal learning context as well. It is hoped that university and secondary school students will continuously use the app after their formal learning experience; they would use the app to observe their surrounding environment through a critical lens, and tackle problems creatively that few of their current generation of instructors can imagine. Furthermore, as the mobile app will be available freely on the app store, anyone from around the world can download and use the app to learn and conduct colorimetric measurement in their own personal and localized context. For instance, an environmental NGO worker from a low-income country could use the app to perform colorimetric measurement and determine the cleanliness of drinking water samples taken in a river without using an expensive spectrophotometer.

## 2.2 Pedagogical Underpinning

For formal learning in laboratory experiment, our mobile app design must support the associated learning outcomes, which are as follows:

1. Explain the technique, theory, and building components of colorimetric measurement.
2. Compare the technique of conventional and mobile app colorimetry.
3. Solve analytical science problems using mobile app colorimetry.
4. Develop analytical methods using mobile app colorimetry to address real-life problem.

These four learning outcomes require students to actively *construct* knowledge in colorimetry and *experience* first-hand the use of colorimetry for tackling analytical science and real-life problem. More specifically, these learning outcomes are related to two well-established theories of constructivist learning and experiential learning. Recent work by Parsons (2017) provides a rubric-based framework for guiding and evaluating mobile learning activity design with respect to different learning theories, among which are constructivist and experiential learning. For constructivist learning, Parsons describes that the mobile activity should "involves (inter)active construction of knowledge by learners", and learners should "have control of the learning process, and time and opportunity to reflect and develop personal meaning". For experiential learning, on the other hand, the mobile activity should be "designed around a cycle of experience, observation, conceptualization, and experimentation, transformed through reflection into new knowledge". These guidelines will serve as useful pedagogical underpinnings to guide the colorimetry mobile apps and laboratory experiment design.

# 3. CONCLUSION

The current study design and create a mobile app that supports active learning in analytical chemistry. Specifically, it makes learning and performing colorimetric measurement more accessible to chemistry students as well as the general public. For further development, a database of different common solutions calibration profiles can be stored on a cloud-base server, which could be accessed by anyone though the mobile app for measuring the concentration of those common solutions. This would help users bypass the calibration process to increase the ease of use. For instance, a housewife could use the app to download the calibration data of off-the-shelf products such as orange juice or salad dressing sauces, and easily measure their concentration using the app to determine whether the sampled product has been diluted. As a result, this app can serve both as an educational and a monitoring tool for the wider general public for causes such as consumer right and environmental protection.

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