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# Evaluation of a Software Enhanced Mobile Phone Based Microscope as a Teaching Tool

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**Abstract**— Microscopes are central to a microbiologist's workflow, but their cost remains out of the reach of students and hobbyists in the developing countries like Nigeria. The cheaper range of microscopes available in schools lack features such as being able to connect to a computer to enable a scientist project a specimen to his class. This project tried to solve this problem, by testing the possibility of a mobile phone based alternative to conventional microscopes. For the purpose of this project, a microscope stand and live streaming android software were built. The microscope stand consisted of a base, a light source, a battery mount, a slide stage and a lens slot. When a mobile phone is placed over the stand, and the appropriate lenses are in place, it becomes possible to see at microscopic levels, using the phone built in camera software. The android software was built to replace the mobile phone's default camera with settings built to optimize microscopy via a mobile phone. The optimizations focused on the white balance and light exposure levels to produce improved results. Also, the android software serves as a collaboration tool, allowing a user to share his camera stream with other nearby devices in real time, over a wireless fidelity network (WiFi). The microscope system was tested with reverse mobile phone lenses and ball lenses. The reverse mobile phone lenses showed greater magnification, but their shape prevented combination of multiple lenses compared to the ball lenses which showed less magnification when used singly, and greater magnifications when used in pairs. The ball lens combinations gave an approximate magnification of 378, which is close to the magnification attainable from the x40 objective lens on conventional microscopes. This proved useful in the identification of ova of intestinal parasites such as *Ascaris lumbricoides* and *Ancylostoma duodenale*. The mobile phone based microscope system has much less depth and resolution than the conventional microscopes. However, it proves that cheaper microscopy with greater potential is possible.

**Index Terms**— android software, microscopy, mobile phone, wireless fidelity

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## 1 Introduction

Conventional microscopes have existed in the medical community for over five centuries since its invention by Zacharias Janssen in the 16th Century [1]. During this period, lots have changed, while much more have remained the same. Traditional microscopy still involves looking through an eyepiece, which focuses light rays via the objective lens, to form the image at the focal point of the eyepiece [2]. This feature has remained primary to microscopy, since the first compound microscopes were created. Hence, advancements have been in the areas of magnification and specificity. Microscopes such as the scanning electron microscopes have made advancements in rather different directions, as they have not only taken microscopy away from its reliance on optic lenses, but as a side effect, have also taken microscopy away from the reach of students and hobbyists. However, scientific advancement over the years have been pushed to its current heights, by students and hobbyists, working from the comfort of their homes, "garages" and school laboratories.

A light microscope (LM) is an instrument of precision that uses visible light and magnifying lenses to examine small objects not visible to the naked eye or in finer detail than the naked eye allows [2]. Magnification is supposedly possible when incident light from an object, passes through a convex lens, to form a magnified image at the focal point of the lens. Magnification, however, is not the most important issue in microscopy. Mere magnification without added detail is scientifically useless, just as endlessly enlarging a small photograph may not reveal any more detail, but only larger blurs. The usefulness of any microscope is that it produces better resolution than the eye. Resolution is the ability to distinguish two objects as separate entities, rather than seeing them blurred together as a single smudge. The history of microscopy has revolved largely around technological advances that have produced better resolution.

The main objectives of this study were :

1. To construct a mobile phone-based microscope using locally sourced materials.
2. To achieve the highest possible magnification with this device.
3. To assess the possibility of sharing microscopic images obtained on this device with other mobile devices in real time via wireless fidelity (WiFi), helping the system serve as a teaching tool.

The rationale for this study is that if more students or hobbyists have access to the tools for their research, the possibilities of growth within the field of Microscopy becomes limitless. This goal would be achieved by using consumer focused technology like the mobile phone, and its lenses, to build a mobile phone powered microscope, which could grow to be an alternative or even replacement for the conventional

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microscope. Also, the microscope would serve well as a low cost teaching tool in institutions in less developed countries, where the cost of microscopes is rather prohibitive.

## 2 METHOD

A prototype system was built for the purpose of this study. The system involved two fronts, the hardware and the software.

### 2.1 The Hardware

Considering that scientists are very much used to their existing tools and the standard already set by the conventional light microscope, this system comprised a base that is similar in components to the regular microscope (Plate 1 and Plate 2).

#### 2.1.1 The Light Source

The light source consists of a single light emitting diode (LED). This was chosen instead of an LED array, to prevent image distortion due to lens flare. Lens flare is the light scattered in lens systems through generally unwanted image formation mechanisms, such as internal reflection and scattering from material non homogeneities in the lens [3]. The light source is powered by a 6F22 9 volt battery, usually used to power transistor radios. The system is wired internally, complete with a switch for turning the light on or off.

#### 2.1.2 The Stage and Phone mount

The stage is basically a plate of acrylic, resting on a bolt system. The stage is transparent, making it suitable for light to pass through from the light source and directly illuminate the sample to be viewed. The sample to be viewed is placed on the stage, directly below the lens system. The phone mount is another plate of acrylic that has a combination of lenses embedded in it. This layer is where the mobile phone to be used is mounted.

#### 2.1.3 The Adjustment System

Adjustment occurs via bolts. When the bolts holding the stage are rotated simultaneously in a clockwise direction, the stage gradually moves towards the upper surface that holds the mobile phone. Rotating the bolts in the opposite direction causes the stage to gradually move away from the phone mount.

#### 2.1.4 The Base

The base houses the light source, the battery, the switch and the electrical connections. It is made of plywood and serves as a stand, holding the other layers of the system in place.

### 2.2 The Software

Increasing magnification alone does not make a good microscope, and does not solve all the pressing problems around microscopy. The software that goes with this system, was written in the JAVA programming language for the android platform, and performs certain vital roles in the system.

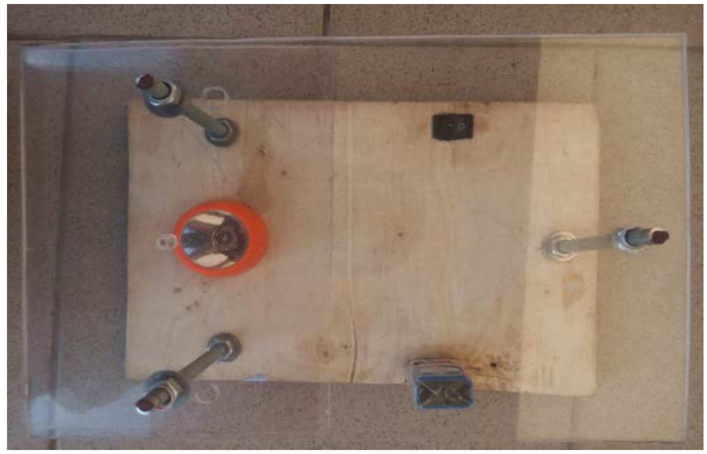

**Plate 1:** Top view of the microscope stand

**Plate 2:** Left side view of the microscope stand

#### 2.2.1 Colour Balancing

The software makes adjustment to compensate for colour defects due to unnatural white light source. It does this by adjusting the white balance of the image, using artificial intelligence based computer vision techniques. In photography and image processing, **colour balance** is the global adjustment of the intensities of the colours (typically red, green, and blue primary colours) [4]. An important goal of this adjustment is to render specific colours – particularly neutral colours – correctly. Hence, the general method is sometimes called gray balance, neutral balance, or white balance [5]. The software uses the Von Kries' method for white balancing, whose theory of rods and three colour-sensitive cone types in the retina has survived as the dominant explanation of colour sensation for over 100 years. The Von Kries motivated the method of converting colour to the LMS colour space, representing the effective stimuli for the long-, medium-, and short-wavelength cone types that are modelled to adapt independently [4].

### 2.2.2 Software based Magnification

The average 13 mega pixel camera is able to take images that measure as much as 3120px in width and 4160px in height (3120px × 4160px), but due to the limited screen size which averages around 750px × 1334px for a 5.5" phone, the phone basically compresses images it takes from its camera, discarding more than half of the total pixel count. The software takes advantage of this, magnifying and cropping the image even more, to more natural resolutions (Plate 3). This cropping and magnification process occurs intelligently, to prevent pixelated images.

### 2.2.3 Stream sharing

The software makes it possible for a hosting device, to share a real time stream of microscopic activity with a list of receivers. For example, the host could be an instructor showing his students something microscopic, while the students would be the receivers. The software does this, by copying the bytes of the camera stream through the processing and magnification filters, and then through a Transmission Control Protocol or Internet Protocol Address Port (TCP/IP port), that can be accessed over a local network (for example, WiFi), through an IP address and port number generated by the software (Plate 4). Other members of the local network can then access the stream using their internet browsers. At the moment, only the google chrome browser has been shown to decode the stream appropriately. The Transmission Control Protocol (TCP) is one of the main protocols of the Internet protocol suite. It originated in the initial network implementation in which it complemented the Internet Protocol (IP). Therefore, the entire suite is commonly referred to as TCP/IP. TCP provides reliable, ordered, and error-checked delivery of a stream of octets between applications running on hosts communicating by an IP network.

## 2.3 The Work flow

The use of this system is similar to the workflow involved in traditional microscopy. The specimen is first placed on a transparent glass slide, which may or may not be stained depending on the specimen in question. The glass slide is then placed on the stage, directly below the lens combination, and the stage is then moved towards the lens combination, using the bolt system. A mobile phone is placed with its camera directly above the lens combination, and then the light source is turned on. The software is then run on the phone, and at this point, the user or scientist is able to see the specimen at a microscopic level.

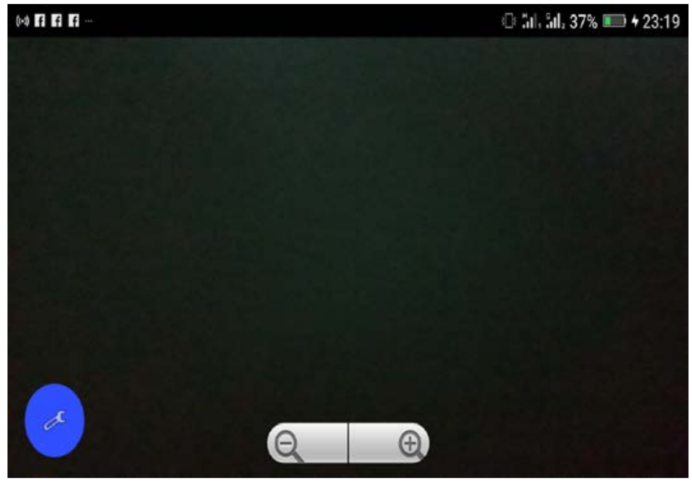


**Plate 3:** Screenshot of the software showing the configuration button and the zoom in and out buttons.

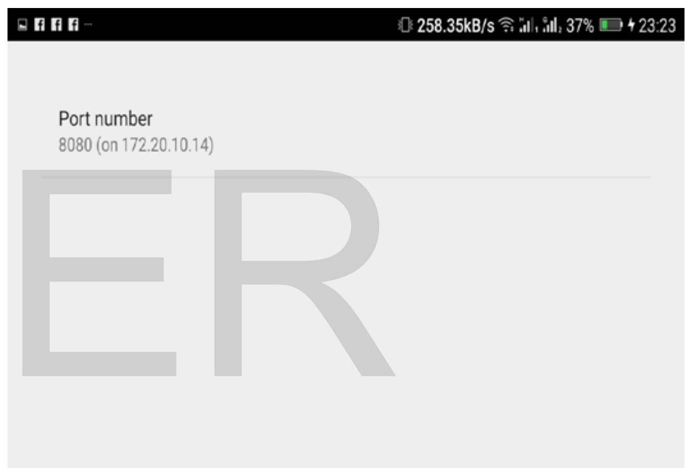


**Plate 4:** Screenshot of the software showing the IP address to be inserted in browsers in order to access the stream

In the event that the scientist intends to share what he is viewing with an audience, he then simply connects to the same WiFi network as his audience, and instructs the audience to key in the IP address that would be shown on the software, into their web browsers. At this point, the audience would also be able to appreciate the camera stream coming from the scientist's device.

## 3 RESULTS

The magnification obtained from the system was calculated as a ratio of the diameter of an average red blood cell compared to the diameter of the red blood cell obtained in our system.

$$m = \frac{O}{U}$$

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Where m is the magnification
O is the object size
U is the image size

For an average red blood cell, The diameter is 7μm
In this system the red blood cell had a diameter of about 10px, which is about 0.264583cm.

Converting the values to meters;
7μm = 0.000007m
0.2644583cm = 0.00264583m

$$m = \frac{0.00264583}{0.000007}$$

= 377.975714286

= 378

Based on this calculation, the obtained magnification is 378, which is close to the magnification obtainable with the x40 objective lens, which gives a magnification of 400. Below are various specimens viewed under the developed system.

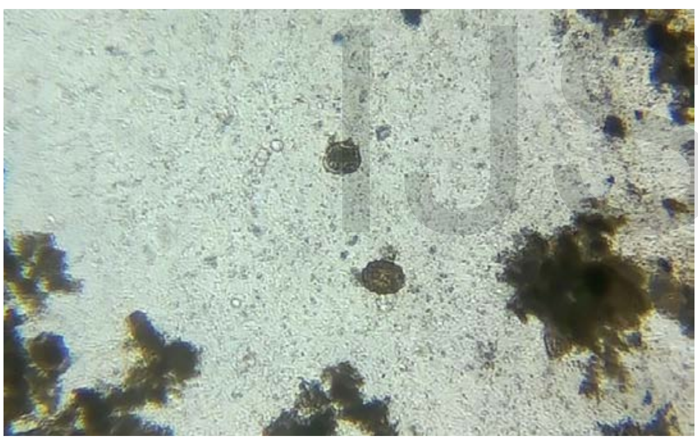

**Plate 5:** Stool sample showing ova of *Ascaris lumbricoides* using two laser pointer beam focusing lenses

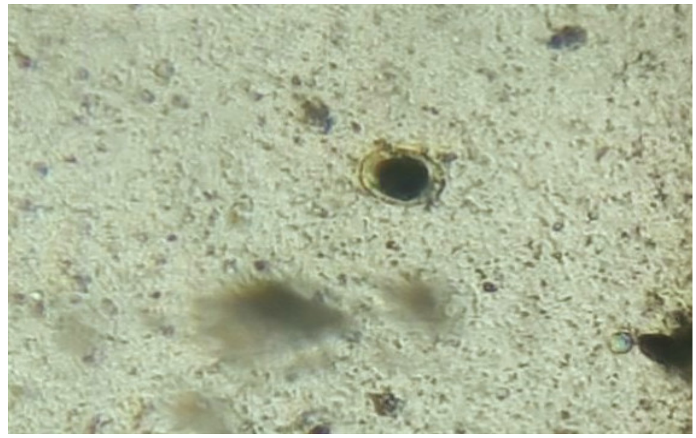

**Plate 6:** Image of ova of *Ancylostoma duodenale* using two laser pointer beam focusing lenses

**Plate 7:** Image of ova of *Ascaris lumbricoides* and *Trichuris trichiura* using two laser pointer beam focusing lenses

## 4 DISCUSSION

The global advancements in technology have been a quantum leap from where we were a decade ago [6]. All spheres of human endeavour have been affected by these positive advances, including the health sector [7], [8], [9], [10], [11]. However, developing countries like Nigeria are yet to catch up with this pace of development [1]. The reasons for these are not far-fetched and include the underdevelopment of the science and technology sector. Tertiary institutions with practical-based courses are deficient in training due to inadequate or outright absence of training aids. Medical Science courses in particular, are worst affected as the graduates of these courses are expected to practise with human beings. Some students do not even have the opportunity of using microscopes and other instruments while in training. This situation is capable of stifling their creativity and enthusiasm for the subject [12], [13]. Many tasks are still being performed with old technology while the rest of the world has moved ahead with newer technologies that accomplish tasks in real-time and are more user-friendly.

In this study, a mobile phone based microscope was developed with locally sourced materials. Several lens combinations were tried. Although the reverse mobile phone lens setup of Switz *et al.* [14] showed considerably better magnifications, it was much more difficult to combine two or more mobile phone lenses for an improved magnification due to their shape. Lenses recycled from regular laser pointers were also tried. These gave much lesser magnification than the mobile phone lens, with considerably smaller usable area, while the edges were blurred or vignetted, due to the shape of the lens. However, this problem was reduced when the lenses were combined and used as a pair, with one stacked on top of the other. The upper lens magnified the usable field of the lens below it, and also reduced the size of the blurred and vignetted region. The combination of lenses gave rise to a considerably higher magnification. A single lens resulted in magnification comparable to x10 magnification on a conventional microscope, while the double lenses combination gave a magnification comparable to x40 magnification on a conventional microscope. In the end, it was better to combine the laser pointer beam focusing lenses for higher magnification than that obtained with the mobile phone lens. The images taken with this setup appeared pixelated when enlarged further, and did not have the depth attainable with conventional microscopes.

## 5 Conclusion

A mobile phone-based microscope, which provided considerable magnification, was developed using locally sourced materials. The software on which the system runs, functions appropriately on the networking front. Users are able to share what they are viewing with others in real time, qualifying it as a teaching tool. However, the software still requires some tweaking in terms of the right sensitivity to light and colour balance in order to give appropriately optimized images.

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