SMART-O-SCOPE
Portable Microscope Using Smartphone

(RESEARCH PAPER)

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ABSTRACT

This study primarily aims to create an improvised microscope using a cellular phone camera and laser lens. The device is composed of three parts—magnifying, illuminating and support. The magnifying part is composed of convex lens from unused laser while the support part of the device is composed of the base which holds the two stages—specimen and cellular phone stages. Two versions of the prototype were created with varying light systems—ambient and built-in. Based from the quality ratings on the images, image produced from the specimen positioned 2.5 cm between the two stages is very clear. It was observed that as the distance of the specimen from the cellular phone stage increases, the quality of the image produced deteriorates.

The improvised cellular phone microscope is comparable to the usual compound light microscope used in biological observations. Test results from the prototype system showed that the improvised microscope was able to achieve the design requirements. It is capable of magnifying objects whether a prepared slide or an opaque specimen. The enclosed body and the installed light system facilitated the control of light that enters the specimen.

Students and teachers will be able to observe various minute specimens using this improvised microscope with ease and in maximized time. This project can provide a wider understanding of organisms that cannot be seen by the naked eye since simplicity and practicality of the equipment designed was considered for future replication and modification.

INTRODUCTION

Background of the Study

Microscope is a device used to magnify various microorganisms which can never be seen by the naked eye. It is composed of three important parts. The magnifying parts

composed of objective and ocular lens functions in enlarging the image to be viewed. The illuminating part provides light source for specimen viewing. Lastly, the mechanical parts function in the adjustment of the stage and lenses to capture the sharpest image possible.

With this special function of magnifying minute materials, microscope is commonly used in understanding physical and behavioral features of organisms in the field of research. Microscope is also widely use in teaching biology and its branches. This tool helps the students in appreciating diversity in living organisms.

One of the problems encountered in the current implementation of the K to 12 Basic Education Program is the lack of equipments that could enhance student's understanding of various concepts. It is a challenge to teach science, particularly topics related to cell and microorganims, the absence of microscope for observation in class. Some schools may have adequate amount of microscope but still not enough to have the observation in a 1:1 ratio. Also, a problem with the existing microscopes in public schools is the convenience in bringing it to the classroom since compound light microscopes are too bulky and requires enough light provision in the working area.

Nowadays, cellular phone is part of daily livings. New models of cellular phones have been built containing features like camera applications. Cameras of these cellular phones work through the help of lens that magnifies image at a desired level. Qualities of the image vary according to the installed specifications of the cellular phone. With this increasing exploration of the features of cellular phones, cellular phone microscopy

become an interest to some. In the field of health, single lens off-chip cellphone microscopy is already developed operated by a complex optical system (Arpa et al., 2012).

Also, studies show that convex lens can magnify organism the same way as the objectives of the microscope function (Morrison and Gardner, 2013). There is a possibility that a cellular phone can capture an image of microorganism with the help of a concave lens (Arpa et al., 2012).

With this prior information, the researchers focused in developing a cheap and portable microscope operated by lens from old laser and cellular phones with built-in camera. This project targets to develop an improvised microscope, from the abovementioned material, that can display and capture image by taking advantage of other cellular phone features.

Statement of the Problem

After conducting this study, it is expected that an improvised cellular phone microscope will be developed. Furthermore, this study aims:

1. create an improvised microscope, with natural light system and with built-in light system, using a cellular phone camera and laser lens;
2. determine the quality of the image produced from the improvised cellular phone microscope;
3. compare the images produced in the improvised device to that of a compound light microscope;
4. compare the images produced in devices with natural light system and with built-in light system;
5. use the device in observing opaque materials like leaf external structures and insect external morphology; and
6. test the device in different cellular phones and gadgets.

Significance of the Study

The primary concern of this study is to determine the feasibility of cellular phone camera partnered with laser lens in magnifying specimens as in the function of a microscope. This device will be of great help to different people in various fields, such as:

Educational Sector. Students and teachers will be able to observe various minute specimens using this improvised microscope with ease and in maximized time. Using the image captured by the cellular phone and projected in its monitor can let three to five observers view the specimen at the same time. Teachers can directly point out the important parts of the specimen and even capture a photo for future reference.

Field of Biological Science. This project can provide a wider understanding of organisms that cannot be seen by the naked eye since creation and operation of this cellular phone microscope is accessible and low-cost.

Scope and Limitations

This study focuses on the creation of an improvised microscope using a cellular phone combined with a laser lens. The development of the device was limited on the usage of a cellular phone specifically Iphone 5s and concave lens from unused laser lights.

The quality of the images produced by the improvised device was evaluated using a visual quality rating assessed by three respondents. The study was conducted from June until August 2014 at Cavite National High School, Cavite City.

METHODOLOGY

Preparation of Materials

The primary materials needed in the creation of the improvised microscope are lens from unused laser light and a cellphone. These two materials will provide the magnifying power for the improvised microscope. The support parts of the microscope include a 4x6-in wood serving as a base; three pieces 4-in bold, nine round nuts, two winged nuts and five washers for attachment. For the stage, a 4x6 in plexiglass was used as stage for the cellphone and a 2x6 in plexiglass for the specimen. A power drill was used in boring holes in the wood and glass support parts.

Figure 1. Materials used in the development of the improvised cellular phone microscope.

Creation of the Improvised Microscope

Following Kmyoshino (2013) and IFLScience (2014) method in creating a viewing stage, three holes were bored into the wooden 4x6-in base. Bolts were inserted

into the holes to fit the two layers of plexiglass. 2x6 in plexiglass specimen stage and above is the 4 x6 in plexiglass cellphone stage. Washers and nuts were used to secure the attached support stages of the device. A yarn was attached to an unused lever of a mechanical liquid eraser to facilitate the adjustment of the specimen stage. See Figure 2 for the diagrammatical sketch of the device.

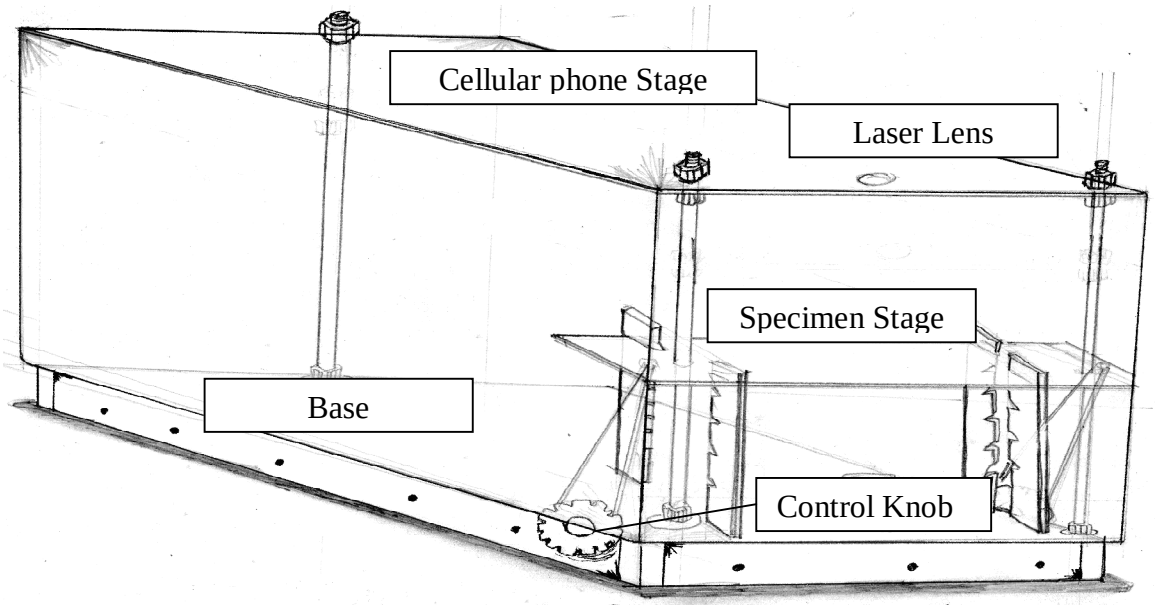

Figure 2. Diagrammatical sketch of the improvised device using ambient light.

Two versions of the device were created. The first version uses the ambient light in the observation area. The second version is enclosed in a box made of illustration board. This enclosed device has a built-in light system using an unused LED torch with modified circuitry (Figure 3).

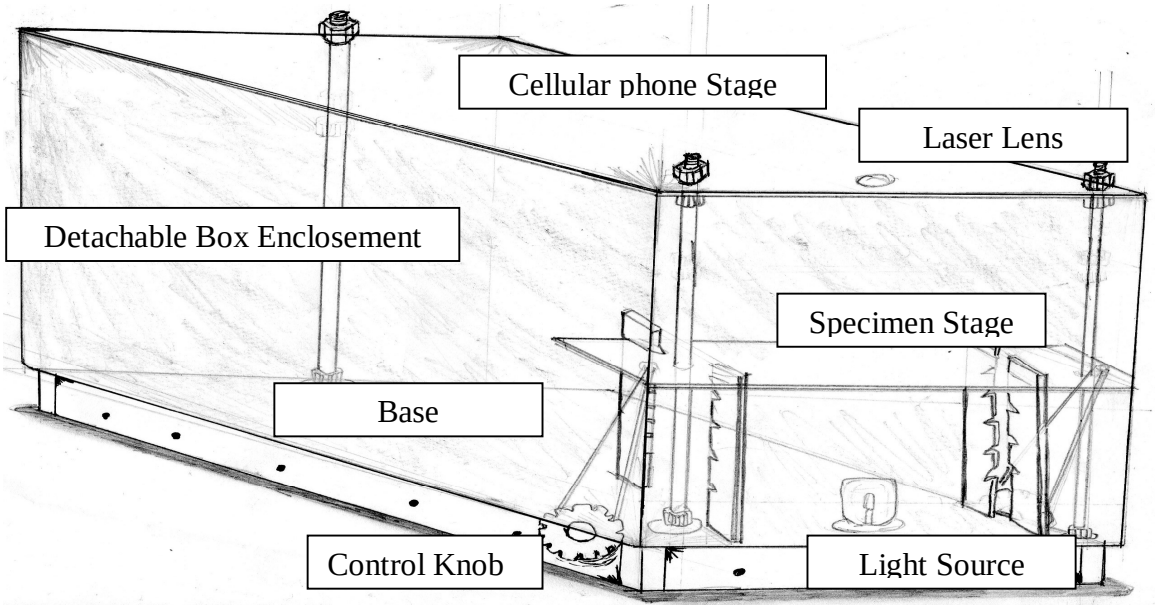

Figure 3. Diagrammatical sketch of the enclosed device.

Testing of the Device

To test the functionality of the device, a prepared slide was placed on the specimen stage and was observed using the cellular phone placed on the support stage. The image produced in the cellular phone monitor was rated by three respondents using the following scale:

Score	**Verbal Description**
4=	Image is very clear, majority of the specimen parts are identifiable
3=	Image is slightly clear, some parts of the specimen hard to be identified

2= Image is visible but majority of the parts are blurred

1= Image cannot be identified

Data Analysis

Qualitative data obtained during the visual quality rating was transformed and converted into a quantitative distribution. Mean was used for all the obtained data in the three ratings performed. Figure 4 summarizes the methodology used in this study.

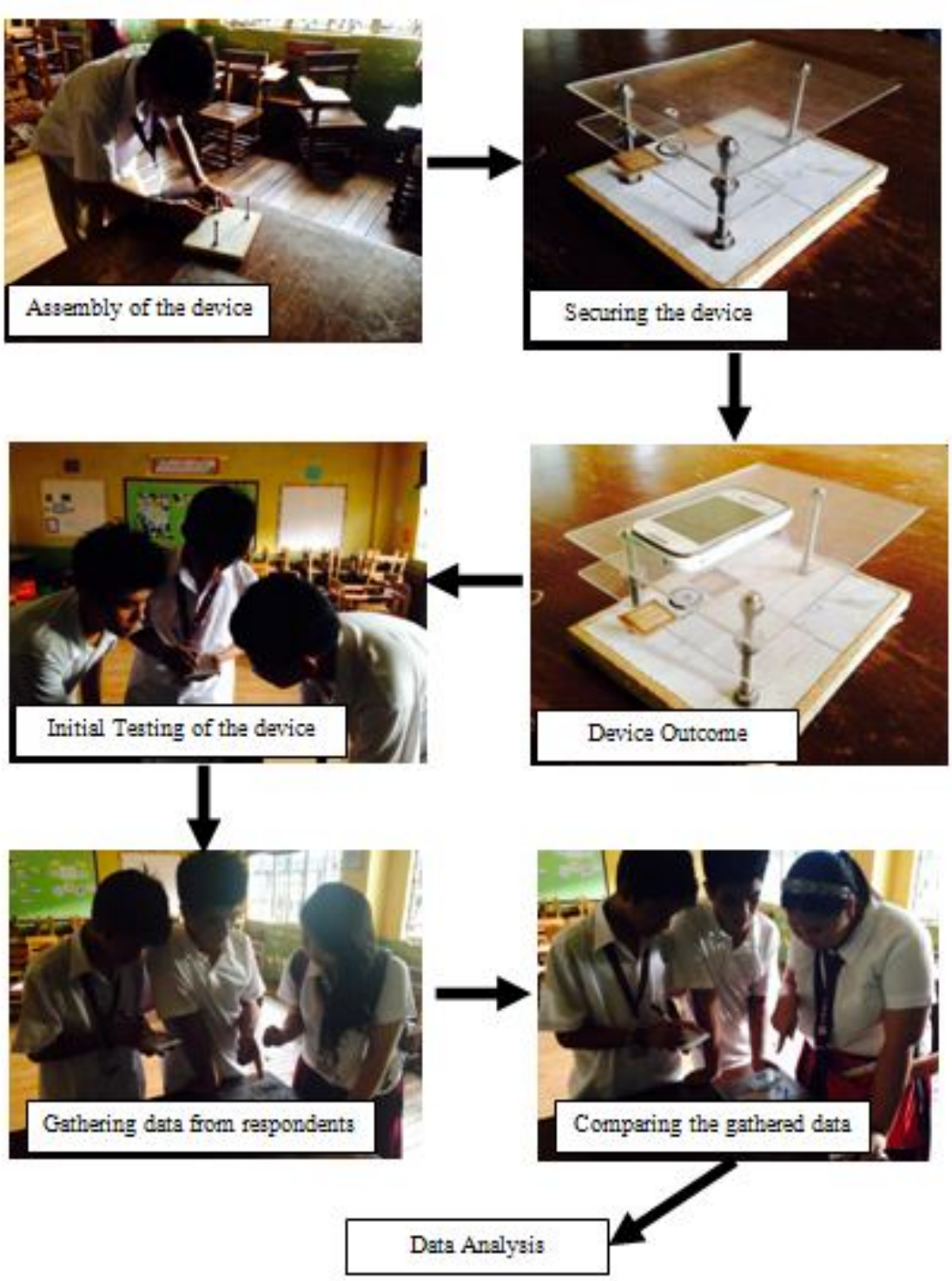

Figure 4. Assembly, testing, data gathering and analysis of the improvised microscope using smartphone.

RESULTS AND DISCUSSION

Specification and Operation of the Improvised Microscope

The created improvised microscope is composed of three parts—magnifying, illuminating and support parts. The magnifying part is composed of convex lens form unused laser light. To provide additional light source during the microscope observation, an LED torch light was installed at the base of the device. Lastly, the support part of the device is composed of the base which holds the two stages—specimen and cellular phone stages. Below is the summary of the specification and operation of the device:

Table 1. Specification, installation and operation of the device.

Specification	The base is made up of an 8x6 in wood, three 4 in bolts supported by three round nuts and washer. This stage serves as the feet of the device that holds the other stages. This also serves as the carrier of the light source. The specimen stage is a 2x6 in. plexi glass that can be adjusted using the built-in lever made from strings and unused mechanical dispenser for correction tape. This stage can be adjusted up and down by moving the knob on the sides. This allows the focusing of specimen based on the size of it. The cellular phone stage is an 8x6 in. plexi glass locked by six round nuts. This stage holds the lens and serves to hold the cellular phone

	during the experiment. In this stage the removed laser lens is installed. A box enclosure can be placed to the device. This box enclosure can cover the sides of the device for a more concentrated light system.
Installation	Assembling is done by fixing the plexi glasses and locking it with the nuts and washers.
Operation	The distance of the specimen stage is adjusted based from the size of the specimen used. The camera of the smartphone to be used is placed on top of the lens in the cellular phone stage. Initial focusing can be done by moving the knob in the specimen stage up and down.

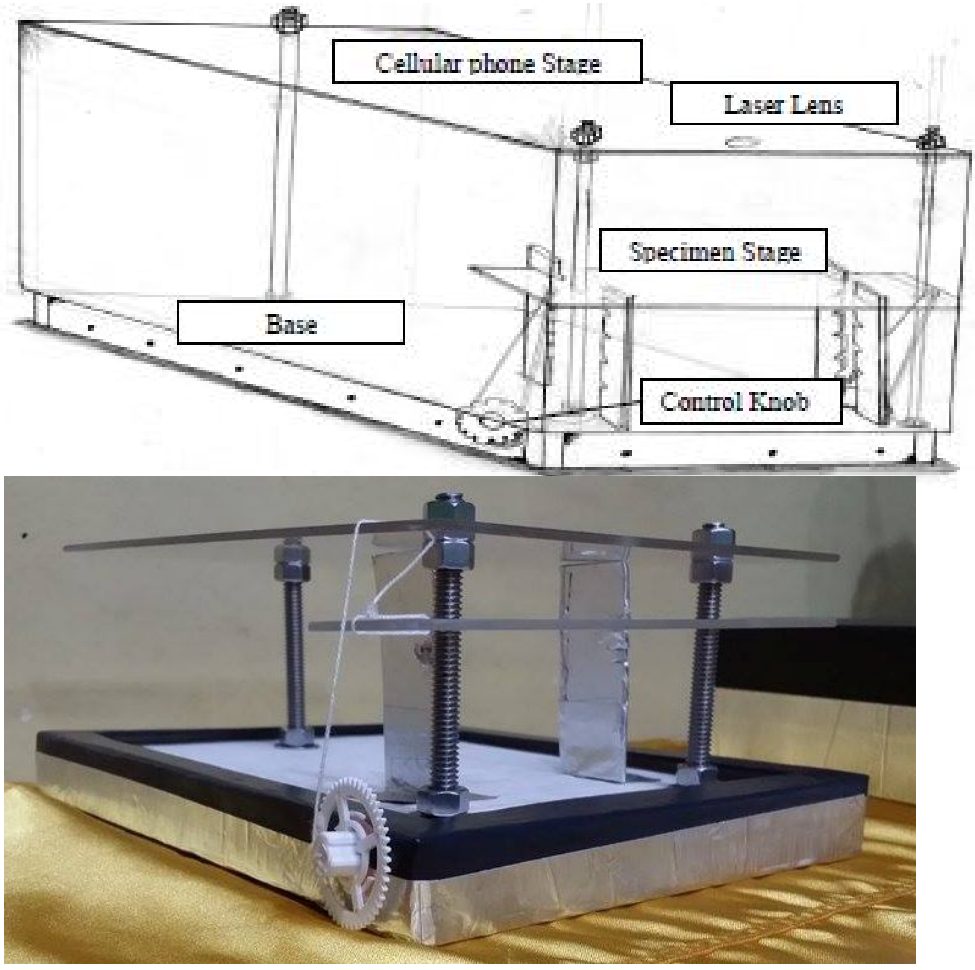

Figure 5. Created improvised microscope powered by cellular phone and laser lens.

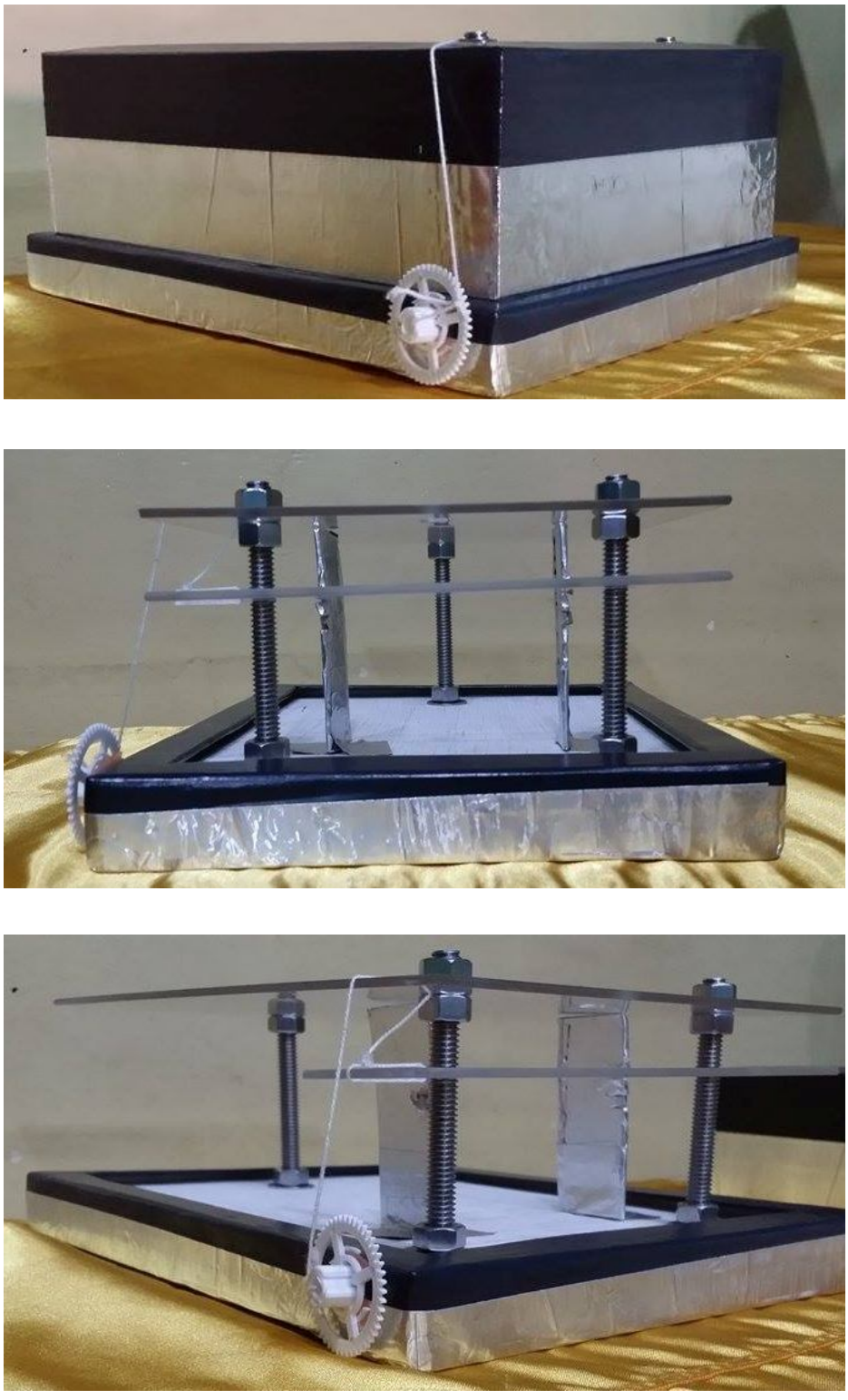

Figure 6. Components of the created improvised microscope powered by cellular phone.

Images Produced by the Improvised Microscope

A specimen of *Hibiscus* stem cross section was observed using the device. Following are the pictorial data on the images projected on the cellular phone at varying distance of specimen stage to cellular phone stage (2.5 cm, 3.5 cm, and 4.5 cm) and cellular phone magnification (1X, 2X and 3X) (Figure 7).

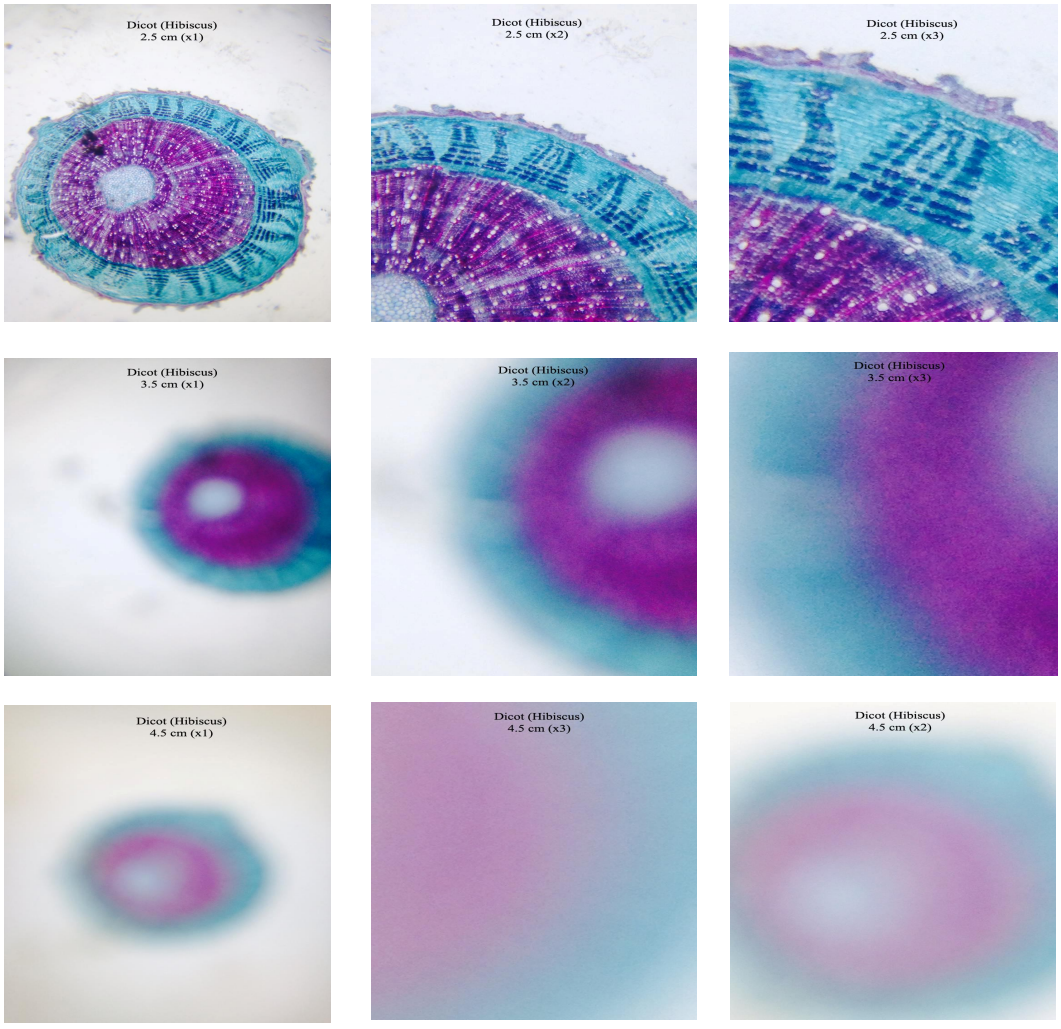

Figure 7. Dicot stem (*Hibiscus*) cross section at varying distance and magnification. Images in the first level were captured at 2.5 cm distance, 1x, 2x and 3x, respectively. Images in the second level were captured at 3.5 cm distance, 1x, 2x and 3x, respectively. Images in the third level were captured at 4.5 cm distance, 1x, 2x and 3x, respectively.

Visual Quality Rating of the Images Produced

Three respondents were tasked to evaluate the images produced by the improvised microscope. Specimens were placed on varying distance of specimen stage to cellular phone stage (2.5 cm, 2.5 cm, and 4.5 cm) and cellular phone magnification (1X, 2X and 3X). Table 2 shows the quality ratings provided by the respondents.

Table 2. Quality rating of images zoomed 1X.

Treatment	Quality Ratings of the Image Produced (x1)				
	Person 1	Person 2	Person 3	Average	Description
2.5 cm	4	4	4	4.00	Image is very clear, majority of the specimen parts are identifiable
3.5 cm	3	2	2	2.33	Image is slightly clear, some parts of the specimen hard to be identified
4.5 cm	2	2	2	2.00	Image is slightly clear, some parts of the specimen hard to be identified

Based from the quality ratings on the images (not zoomed), image produced from the specimen positioned 2.5 cm between the two stages is very clear. Majority of the parts in the specimen are identifiable. It was observed that as the distance of the specimen from the cellular phone stage increases, the quality of the image produced deteriorates.

Table 3. Quality rating of images zoomed 2X.

Treatment	Quality Ratings of the Image Produced (x2)				
	Person 1	Person 2	Person 3	Average	Description
2.5 cm	4	4	4	4.00	Image is very clear, majority of the specimen parts are identifiable
3.5 cm	3	2	2	2.33	Image is slightly clear, some parts of the specimen hard to be identified
4.5 cm	2	1	1	1.33	Image is visible but majority of the parts are blurred

Based from the quality ratings on the images zoomed two times, image produced from the specimen positioned 2.5 cm between the two stages is very clear. Majority of the parts in the specimen are identifiable. It was observed that as the distance of the specimen from the cellular phone stage increases, the quality of the image produced deteriorates.

Table 4. Quality rating of images zoomed 3X.

Treatment	Quality Ratings of the Image Produced (x3)				
	Person 1	Person 2	Person 3	Average	Description
2.5 cm	4	4	4	4.00	Image is very clear, majority of the specimen parts are identifiable
3.5 cm	3	2	2	2.33	Image is very clear, majority of the specimen parts are identifiable
4.5 cm	2	1	1	1.33	Image is visible but majority of the parts are blurred

Based from the quality ratings on the images zoomed two times, image produced from the specimen positioned 2.5 cm between the two stages is very clear. Majority of the parts in the specimen are identifiable. It was observed that as the distance of the specimen from the cellular phone stage increases, the quality of the image produced deteriorates.

As a summary, the distance between the specimen stage and cellular phone stage that produces the best quality of image is 2.5 cm. The image quality does not vary as the image is being magnified using the zoom feature of the cellular phone.

Images Produced in the Improvised Microscope and Compound Light Microscope

Figure 8 shows the images produced in the improvised device (left side) and the images from a compound microscope (right side).

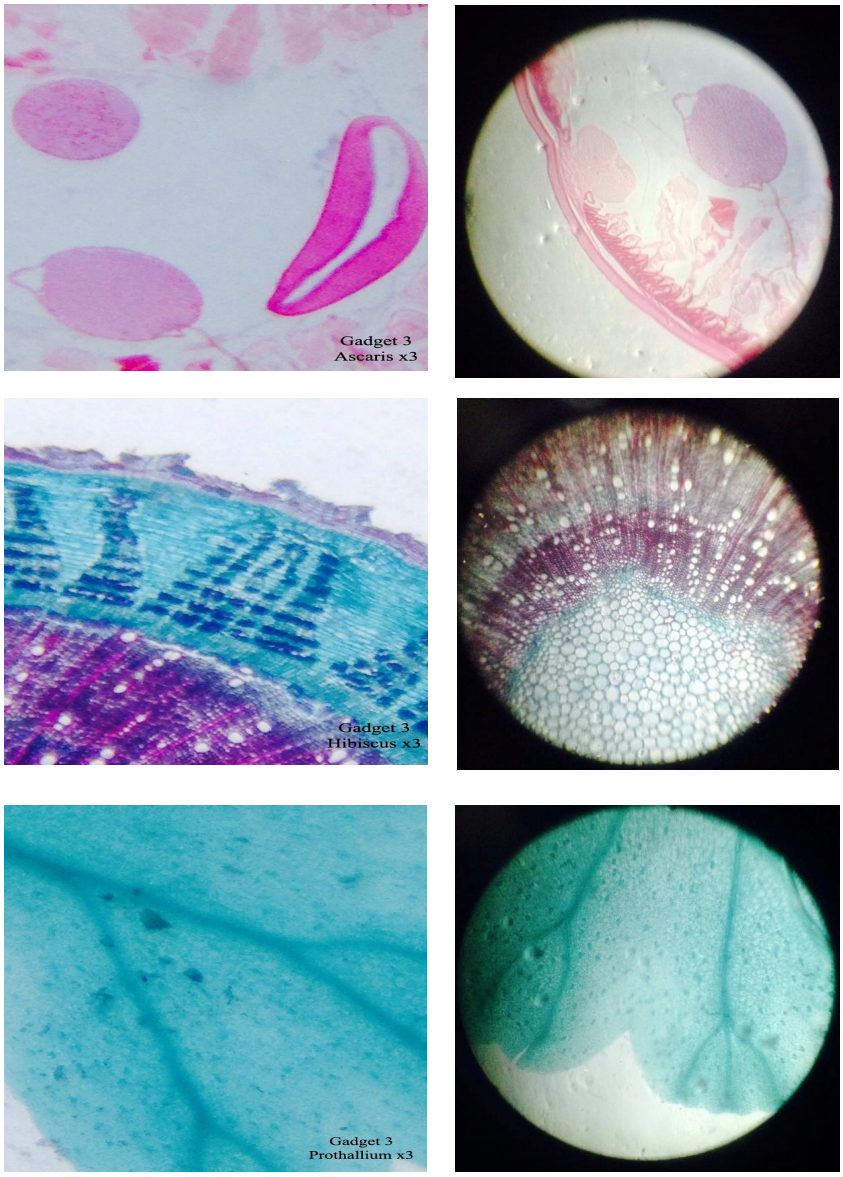

Figure 8. Images captured from the improvised microscope (left) and compound light microscope (right). (First level: *Ascaris* cross-section; Second level: *Hibiscus* stem cross-section; Third level: Fern prothallia sporophyte)

Based from the images captured, it can be inferred that components of the image can be seen at a larger scope or greater area in the improvised device. Vividness of the image in the improvised device is also evident. This can be attributed to the auto-focus function of cellular phone cameras that makes the image clear. One of the advantages that can be obtained from the usage of the improvised device is the ease in observation. One of the problems encountered in microscope viewing is the high risk of experiencing eye. With the improvised device, viewing can be done at a farther distance and maximized number of viewers.

Images Produced in Different Light System

Two versions of the device were prepared. The first device utilizes the ambient light in the observation area. This first version can be transformed into an enclosed system by placing a box covering made of illustration board. Figure 9 shows the images produced in the device manipulating the light system. Images on the left are produced using the ambient light system while the images on the right are from the enclosed system with built-in LED torch light inside. Table 5 summarizes the ratings done to the images.

Table 5. Quality rating of images from ambient and built-in light systems.

Treatment	Quality Ratings of the Image Produced				
	Person 1	Person 2	Person 3	Average	Description
Ambient Light	4	4	4	4.00	Image is very clear, majority of the specimen parts are identifiable
Built-in Light	4	4	3	3.67	Image is very clear, majority of the specimen parts are identifiable

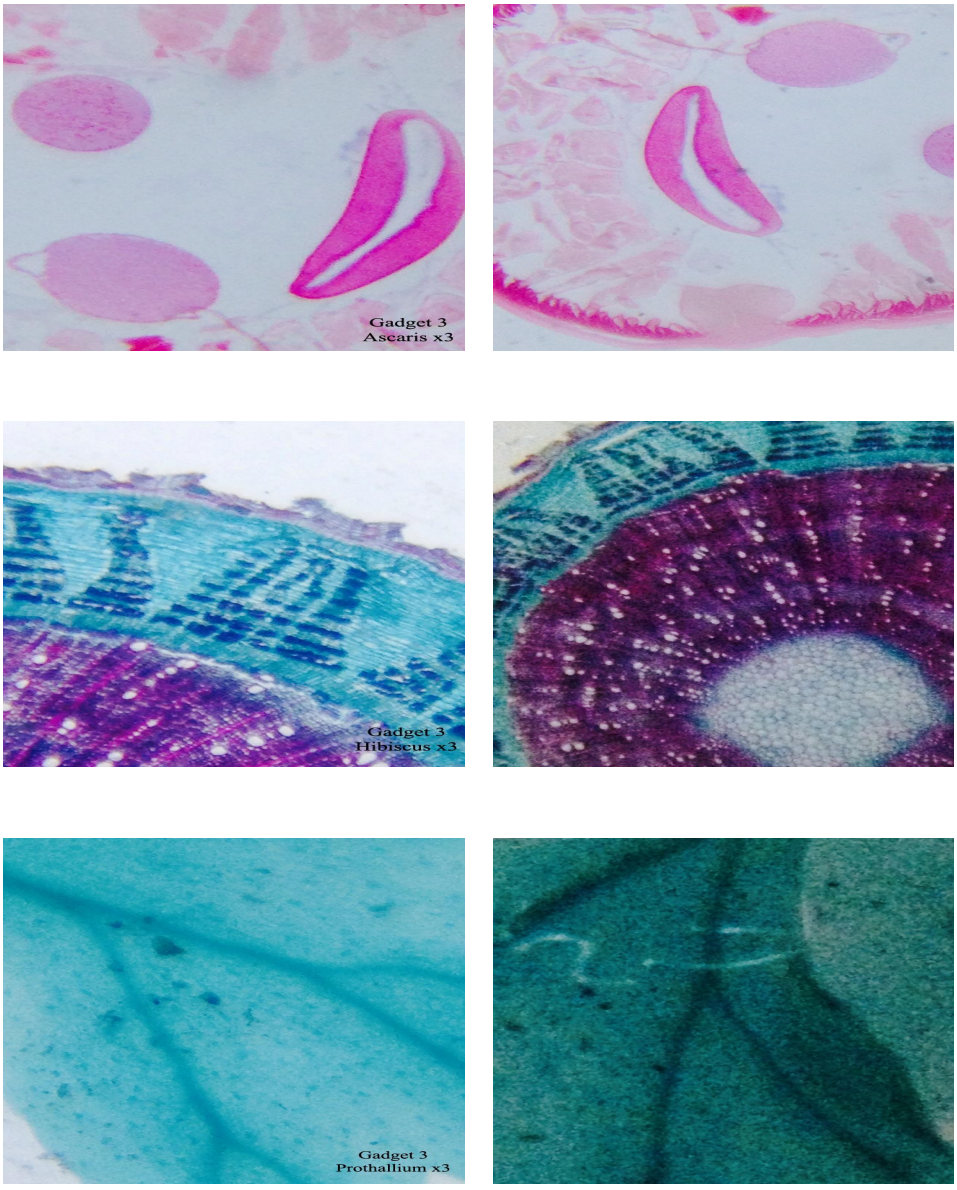

Figure 9. Images captured from the improvised microscope using ambient light (left) and enclosed improvised microscope using built-in light (right). (First level: *Ascaris* cross-section; Second level: *Hibiscus* stem cross-section; Third level: Fern prothallia sporophyte)

Both of the images were rated to be clear and identifiable, in the average. One conspicuous feature of the images in the ambient light system is that the contrast between the background and the specimen itself is not the evident. This can be attributed to the uncontrolled amount of light that enters the system; light can enter in any direction. In contrast with the enclosed system, brightness of the image is darkened making some parts of the specimen to be sharpened. However, it can also be observed that there will be times that the image will be to dark or too light depending on the slide preparation. This scenario suggests that the built-in light source inside can be modified by adding an adjustor to the brightness of light.

Observing Opaque Materials in the Improvised Device

In studying Biology, particularly diversity in organisms, morphological structures of multicellular individuals are of great importance. These multicellular individuals vary in morphology both in the external and internal features. Thus, the use of magnifying devices is necessary to put details on their morphology. Using the improvised microscope, observation of various opaque materials was done using the abaxial side of the leaf and ant body. Figure 10 and 11 show the images of the leaf abaxial and ant body. Table 6 includes the quality ratings of the images produced.

Table 6. Quality rating of images from ambient and built-in light systems.

Treatment	Quality Ratings of the Image Produced				
	Person 1	Person 2	Person 3	Ave	Description
Ambient Light	4	4	4	4.00	Image is very clear, parts are identifiable
Built-in Light	4	4	3	3.67	Image is very clear, parts are identifiable

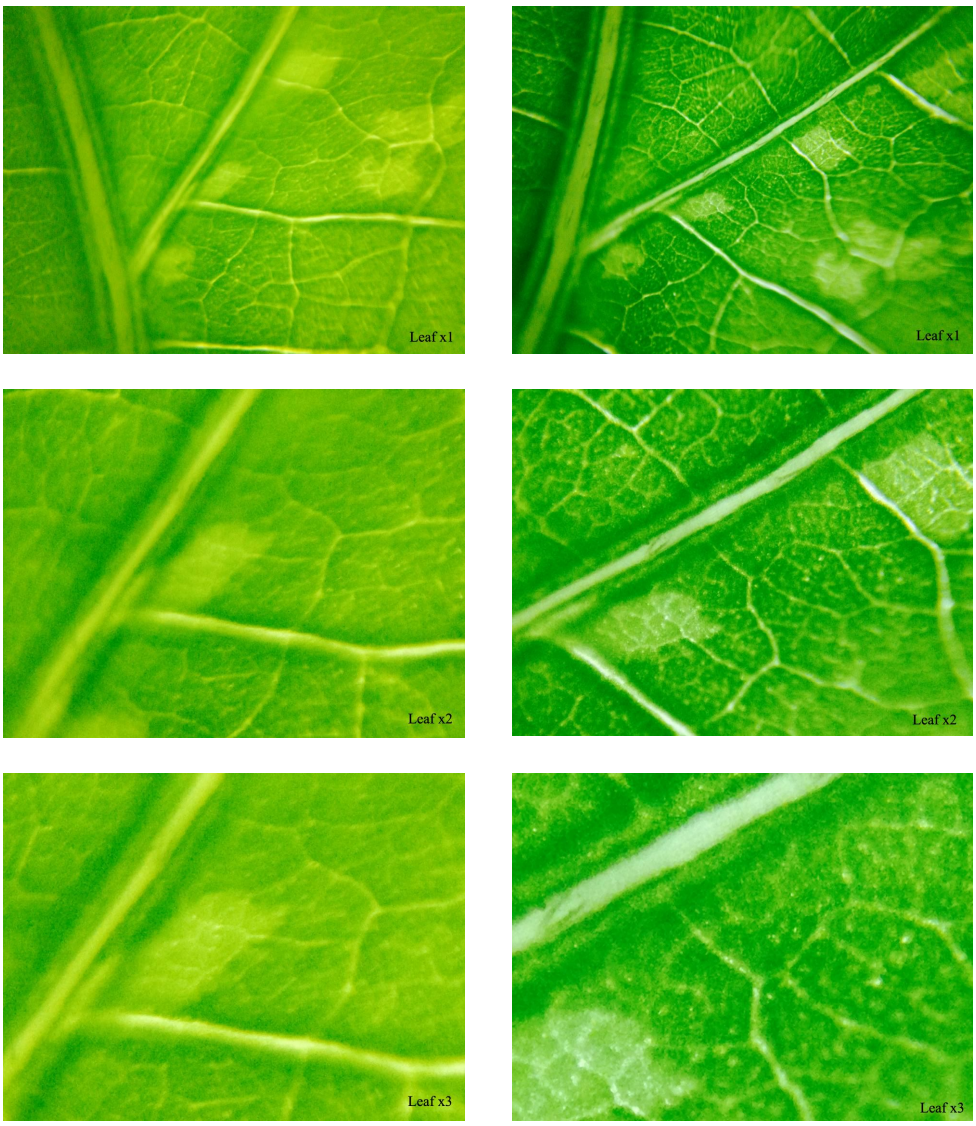

Figure 10. Leaf abaxial side at ambient light system (left) and enclosed light system (right) in varying magnification (Level 1:1X, Level 2: 2X, and Level 3: 3X).

Venation pattern of the leaf, up to the tertiary level can be observed clearly. This capability of the device to observe opaque materials increases its functionality in observing specimens in the field with ease in bringing a portable microscope.

Figure 11. Ant body at ambient light system (left) and enclosed light system (right) in varying magnification (Level 1:1X, Level 2: 2X, and Level 3: 3X).

The above images show the morphology of ant observed under the improvised microscope. With the larger area for specimen, as compared to the small stage of compound microscope, specimens can be manipulated easily and positioned in such a way that the specific portion can be viewed clearly. This will be of great significance in

understanding behavior of various organisms by observing live movements of the organism or even taking a video or directly connecting the smart phone to a larger screen like television screen, computer screen or even LED projectors.

Images Captured Using Different Cellular Phones (Tablet)

Compatibility of the device in varying gadgets was also tested. Three different devices were fit into the stage and the images seen were captured (Figure 12). The following devices were used in capturing the images:

1. Samsung Galaxy S Duos with 5 megapixel camera
2. Samsung Galaxy Tablet 7.0 with 3 megapixel camera
3. Apple iPhone 5C with 8 megapixels camera

The captured images suggest that the improvised microscope is compatible to any kind of cellular phone or tablet that has a rear camera. The quality of images varies with the specifications of the built-in camera. Nonetheless, the parts of the specimen are still identifiable but if the observation requires a more detailed examination of the specimen parts then it is best to use the cellular phone with the greatest quality of image that can be produced.

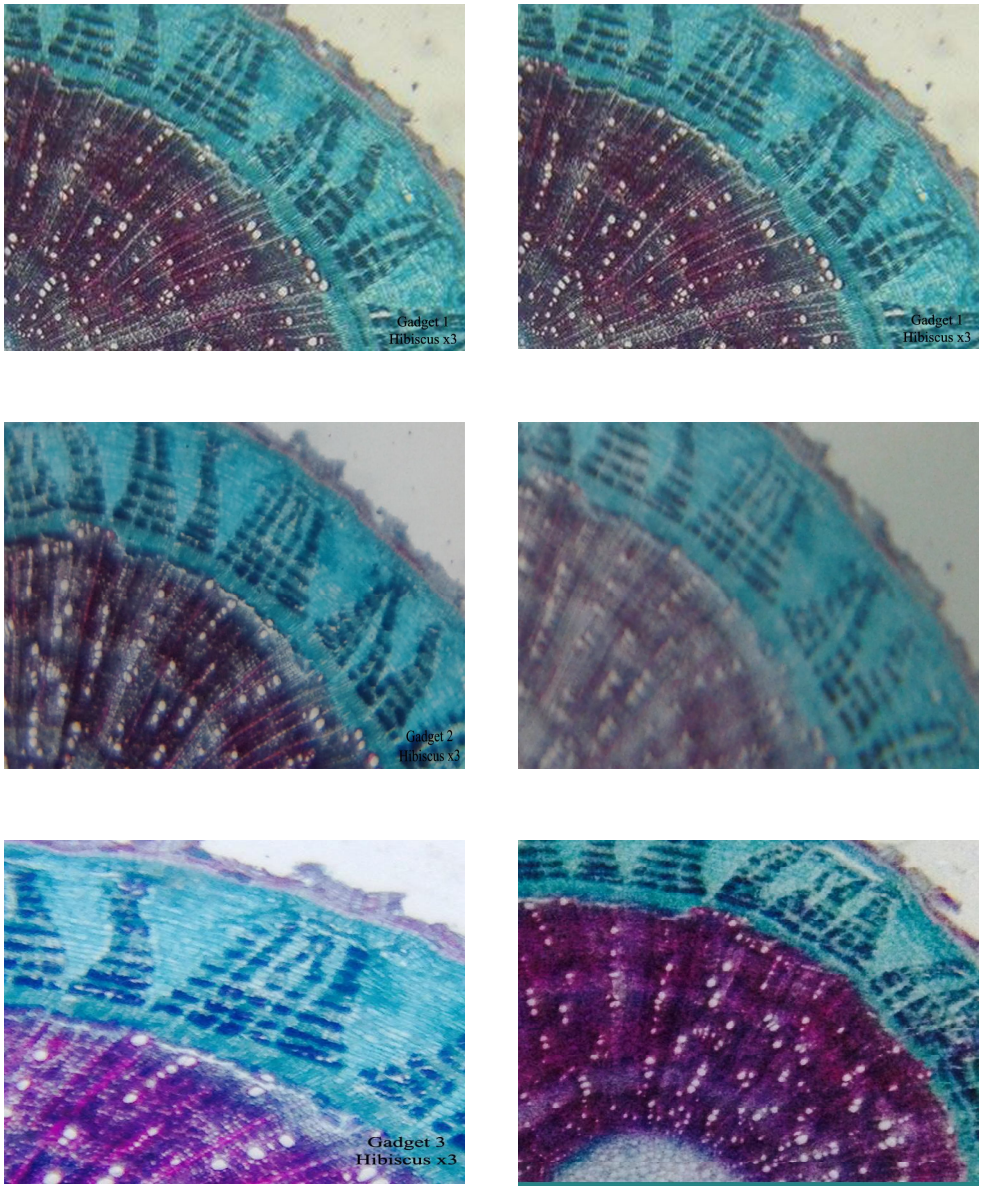

Figure 12. *Hibiscus* cross section using different cellular phones/ tablet. (Level 1: Samsung Galaxy S Duos with 5 megapixel camera; Levell 2: Samsung Galaxy Tablet 7.0 with 3 megapixel camera and Level 3: Apple iPhone 5C with 8 megapixels camera)

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

This study primarily aims to create an improvised microscope using a cellular phone camera and laser lens. The created improvised microscope is composed of three parts—magnifying, illuminating and support parts. The magnifying part is composed of convex lens form unused laser light. To provide additional light source during the microscope observation, an LED torch light was installed at the base of the device. Lastly, the support part of the device is composed of the base which holds the two stages—specimen and cellular phone stages. The device can be operated by adjusting the distance of the specimen stage based from the size of the specimen used. The camera of the cellular phone to be used is placed on top of the lens in the cellular phone stage. Initial focusing can be done by moving the knob in the specimen stage up and down.

Three specimens were observed under the microscope specifically dicot stem (*Hibiscus*), ascaris cross section and fern prothallia. Based from the quality ratings on the images, image produced from the specimen positioned 2.5 cm between the two stages is very clear. Majority of the parts in the specimen are identifiable. It was observed that as the distance of the specimen from the cellular phone stage increases, the quality of the image produced deteriorates. As a summary, the distance between the specimen stage and cellular phone stage that produces the best quality of image is 2.5 cm. The image quality does not vary as the image is being magnified using the zoom feature of the cellular phone.

The images captured from the improvised microscope were compared to images captured from compound light microscope. Based from the observations done, components of the image can be seen at a larger scope or greater area in the improvised device. Vividness of the image in the improvised device is also evident. This can be attributed to the auto-focus function of cellular phone cameras that makes the image clear. One of the advantages that can be obtained from the usage of the improvised device is the ease in observation. One of the problems encountered in microscope viewing is the high risk of experiencing eye. With the improvised device, viewing can be done at a farther distance and maximized number of viewers.

Two versions of the device were prepared. The first device utilizes the ambient light in the observation area. This first version can be transformed into an enclosed system by placing a box covering made of illustration board. Both of the images were rated to be clear and identifiable, in the average. One conspicuous feature of the images in the ambient light system is that the contrast between the background and the specimen itself is not the evident. This can be attributed to the uncontrolled amount of light that enters the system; light can enter in any direction. In contrast with the enclosed system, brightness of the image is darkened making some parts of the specimen to be sharpened.

Various opaque materials were also subjected to observation under the improvised microscope. Images captured were able to show the different morphological features of leaf abaxial side and ant external morphology. This can provide an avenue for better exploration of diversity in flora and fauna.

Lastly, the improvised microscope was tested in different cellular phones and tablet to check for its compatibility. All of the tested devices were able to provide images of the specimen. However, the quality of the images varies depending on the specifications of the gadget. There is no single gadget is compatible to the improvised microscope.

The improvised cellular phone microscope is comparable to the usual compound light microscope used in biological observations. The device was developed using inexpensive and simple in structure materials. Test results from the prototype system showed that the improvised microscope was able to achieve the design requirements. The simplicity and practicality of the equipment designed was considered for future replication and modification.

It is suggested that further exploration of the lens usage be done to improve the quality of the image under observation. Also, adding other light source or experimenting on the position of the light source in the setup may increase the vividness and sharpness of the images.

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