# Low-cost & Effective Homemade Microscope: A Project

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Abstract:

*This work is to study a construction of a simple old-fashion microscope using a glass bead lens made by melting a glass capillary tube in the school biology laboratory with various sizes for different magnification. Some images of specimen samples were taken using a digital camera of a mobile phone or a computer tablet. The quality of the image is good enough for using in the classroom or out of school activities. This simple microscope can be transformed into a polarizing microscope using two polarizing sheets: the polarizer and the analyzer. The specimen can be seen over the dark background, and it does not need to be stained.*

Keywords: *glass bead lens, microscope, magnification, polarizing microscope*

## 1. Introduction:

One problem in studying biology in some areas is the lack of demonstration equipment. This is because those equipment including microscopes, are not available or are too expensive. Students can themselves construct such equipment from materials available in daily life or in normal school laboratory. Studying biology without a microscope or studying from the pictures in a book only is not an effective education.

As a matter of fact, students can easily make a simple microscope with a single lens. The lens of such a microscope can be made of melted or "blown" glass. Robert Hooke[1] used this form of lens at one time and in his Cutlerian lectures of 1679 he told how it was made:

[1] https://www.britannica.com/biography/Robert-Hooke

*"... Take then a small rod of the cleanest and clearest glass you can procure; then by melting it in the flame of a Lamp made with Spirit of Wine, draw it out into exceeding fine and small threads; then take a small piece of these threads, melt the end of it, till you perceive it to run into a little ball or globule of the bigness desired; then suffer it to cool, and handling it by the aforesaid thread of glass, fix it upon the side of a thin plate of Brass, Silver or the like, that the middle of it may lie directly over the middle of a small hole pricked through the said thin plate with a needle: then holding this plate close to the eye, look through the aforesaid Globule, you fix the object you would examine; so that it may be at a due distance from the said little Globule, you will perceive the minute parts thereof very distinct..."*[2]

In fact, the first man who made important discoveries with the single lens microscope was Antony Van Leeuwenhoek[3], born in 1632. Leeuwenhoek's microscope was made of ground lens not the blown spherical lens used by Hooke. But both lenses work quite well. A blown lens, however, is the easier of the two to make. In general, magnification of a simple magnifier is not high. To increase the magnification of a spherical lens of the microscope, the diameter of the lens must be reduced. To see the enlarged image both the eye and the object must be placed even closer to the lens. The great advantage of the simple microscope in providing an image relatively free from chromatic aberration soon led to the use of inexpensive small lenses produced by melting glass capillary rods. According to Robert Hooke's discovery, a microscope lens can be made from melting a capillary tube in biology laboratory using a gas burner. A glass-bead lens is assumed to be a thick lens[4].

The focal length, f, of a thick lens can be expressed as -

$$\frac{1}{f} = (n-1)\left[\frac{1}{R_1} - \frac{1}{R_2} + \frac{(n-1)d}{n.R_1.R_2}\right] \quad (1)$$

where n is the index of refraction of lens glass, d is thickness, $R_1$, and $R_2$, are radii of curvature of the two lens surfaces. For a spherical lens, $R_1$, and $R_2$, are equal to the radius of a sphere R but different in sign and d is equal to 2R (see Figure 1). Then, equation (1) becomes.

$$f = \frac{n.d}{4.(n-1)} \quad (2)$$

Magnification, M, of a lens can be found from the formula.

$$M = \frac{250}{f} \quad (3)$$

[2] Bradbury, S. (1967). The Evolution of the Microscope. Pergamon Press Ltd.
[3] https://www.britannica.com/biography/Antonie-van-Leeuwenhoek
[4] DeRobertis, E., Saez, F., and DeRobertis, E., Jr. (1975). Cell Biology, W.E. Saunders Company.

where f is a focal length of a lens in millimeters. From equation (2) and (3), we get.

$$M = \frac{1000(n-1)}{n.d} \tag{4}$$

Assuming that n of the glass capillary rods is about 1.5 and the lens diameter d is 1 mm., a magnification of this single lens microscope can be calculated by using a thick lens formula. Under this condition, the magnification power of the microscope is 250 as shown in Figure 1.

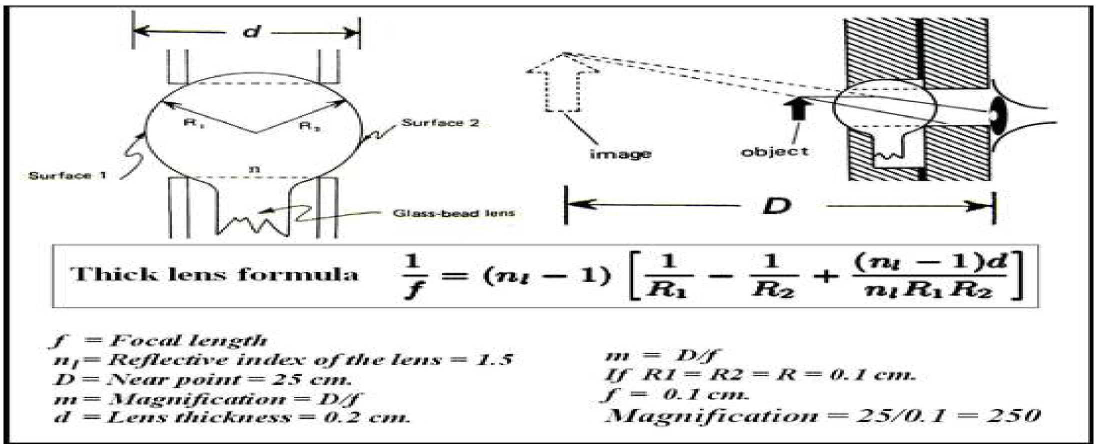


Figure 1. Determining the magnification

2. Literature Review:

Since the beginning of microscopy studies, there have been studies on the pinhole effect, which helps to see small objects clearly, for example, the study of Lee Van Hook's work[5]. Robert Hooke[6] proposed making lenses from fused glass spheres and using them as a single lens microscope for studying small living things and wrote in his book Microscopia[7] of minute bodies. There are many types of lenses used for microscopes, from single lenses or magnifiers to compound lenses[8].

In studying biology of the schools, there is a need of many microscopes in the classroom for students. Therefore, there are studies of a simple, cheap microscope, such as the development of a water drop microscope[9] or clear liquid used to make the lens of a microscope.

In viewing of images from an early microscope, it was based on visual drawings, such as Hooch's work. Later, a microscope with a camera was developed with built-in photo and video capture

[5] https://ucmp.berkeley.edu/history/leeuwenhoek.html

[6] https://www.rct.uk/collection/1090263/micrographia-or-some-physiological-descriptions-of-minute-bodies-made-by

[7] https://physicsmuseum.uq.edu.au/single-lens-microscope

[8] https://daily.jstor.org/the-evolution-of-the-microscope/

[9] Yingprayoon, J., (1979). An Inexpensive Teacher-Made Microscope. In Proceedings of the 2nd ICASE-Asian Symposium on Low-Cost Equipment for Integrated Science Education at all Levels, Quezon City, the Philippines, December 26-31, 1979, 119-127.

camera. But they are expensive and not commonly available in ordinary schools. When the digital camera was developed, this makes recording images from a microscope convenient and inexpensive.

When mobile phones were developed, they could take photos and videos. This makes recording images from a microscope very possible and convenient. Therefore, there are study of using mobile phones with cameras to take images from microscopes[10].

In addition to the development of the microscope, specimen staining has also been developed to make detailed images clearer[11]. Microscopes have been developed using the Polarization technique[12], allowing clear images to be seen without staining.

It would be profitable for biology education to find a way to build a simple, inexpensive microscope and to develop microscopy techniques that can be used by many students in common classrooms.

## 3. Aims of this Project:

The aim of this project:

i) to study how to make a glass bead lens for a simple microscope.
ii) to study the physical properties of the glass bead lens
iii) to study how to utilize a simple microscope in the classroom as well as out of school science activities.
iv) to study how to use a mobile phone with a simple microscope.
v) to study how to make a polarizing simple microscope.

## 4. Materials and Methods:

### 4.1 Lens Making and Assembling of a Microscope:

The lens of the microscope can be made from a glass capillary tube in the school biology laboratory. First clean the glass tube with alcohol and then hold the tip of the tube in the flame of a Bunsen burner or a burner of the kitchen stove. When the tip of the tube is melted until a tiny bead is formed with a diameter of approximately 2 or 3 mm. (see Figure 2). Use a file to cut a glass bead lens from the capillary tube. The glass bead is then immersed in alcohol a few times to be cleaned. The glass-bead lens is now finished and ready for further steps as shown in Figure 3.

[10] H. H. Myint, A. M. Marpaung, H. Kurniawan, H. Hattori, and K. Kagawa, "Water droplet lens microscope and microphotographs," Phys. Educ. 36, 97-101 (2001).
[11] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7365514/
[12] https://courses.lumenlearning.com/suny-microbiology/chapter/staining-microscopic-specimens/

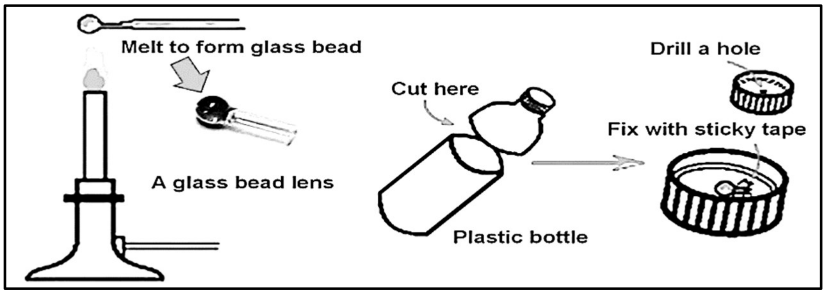


Figure 2. How the lens of a microscope is made and fixed to a microscope housing.

*[Source- Photographs taken by the Research Group]*

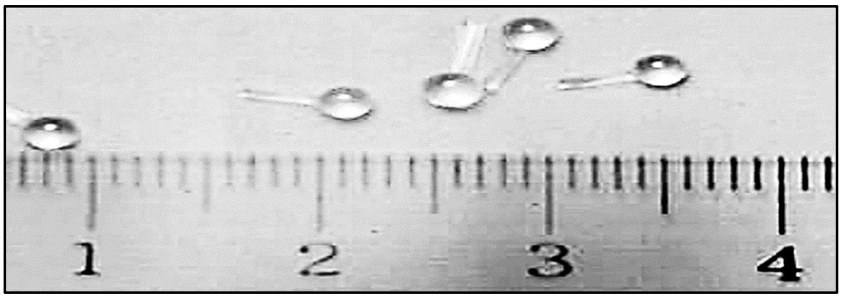


Figure 3. Actual microscopic images taken using a normal digital camera.

*[Source- Photographs taken by the Research Group]*

In this study we made 4 sizes of glass bead lens. Glass beads of 2, 2.5, 3 and 3.5 mm. in diameter are formed to be used as lenses of a simple microscope. An empty water bottle can be used as a microscope housing. Figure 2 shows how to make this simple microscope. Drill a hole in the cap of the bottle and fix the lens across the hole with sticky tape.

The cells of an onion skin are generally rectangular in shape and viewed by using sticky tape instead of a microscope slide as shown in Figure 4. The focus of the microscope can be adjusted by turning the cap to properly adjust the distance between the specimen and the lens. The specimen can be stained with a drop of yellowish-brown gram's iodine to see nuclei of onion cells. This actual simple microscope is shown in the Figure 5.

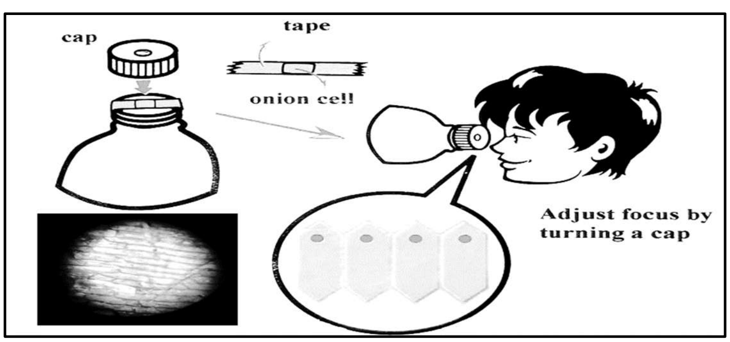


Figure 4. How to prepare and to view a specimen.

*[Source- Photographs taken by the Research Group]*

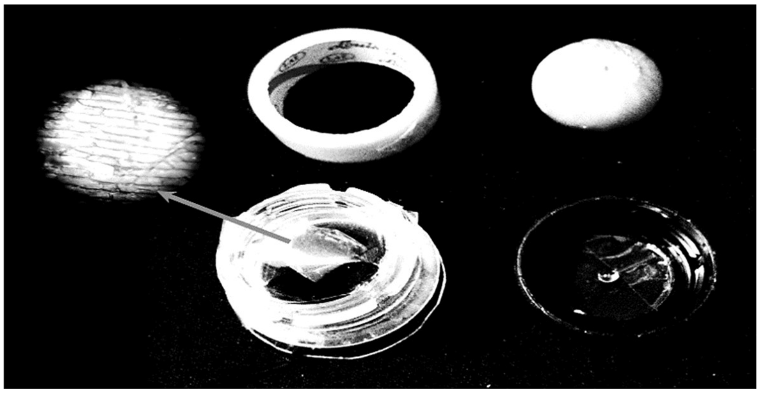

Figure 5. Actual simple microscope
*[Source- Photographs taken by the Research Group]*

## 4.2 Making A Simple Polarizing Microscope:

This simple microscope can be transformed into a polarizing microscope using two polarizing sheets: the polarizer and the analyzer. The polarizer is placed below the specimen and the analyzer is placed above the lens (see Figure 6). In the crossed position, polarized light is not transmitted. Under this condition, if a birefringent specimen is placed on the stage, a plane of polarization will deviate according to the retardation introduced by the object. Birefringence depends on the structural properties of the specimen; therefore, a polarizing microscope can be used for analyzing cell structure indirectly. The specimen can be seen over the dark background, and it does not need to be stained.

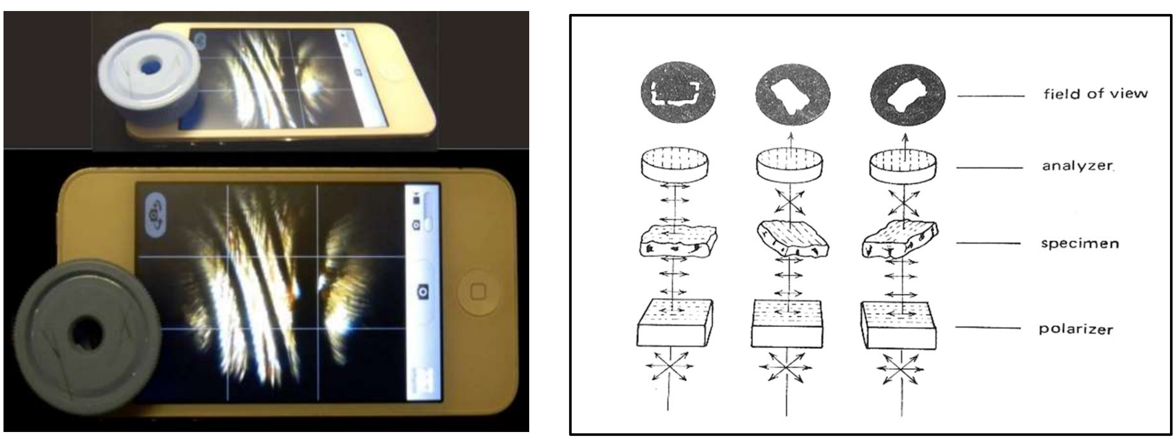


Figure 6. Principle of a simple polarizing simple microscope
*[Source- Photographs taken by the Research Group]*

## 5. Results Revealed and Discussion:

It is possible to take a photo or a video clip from this microscope by using a digital camera of a mobile phone as shown in Figure 7 and 8.

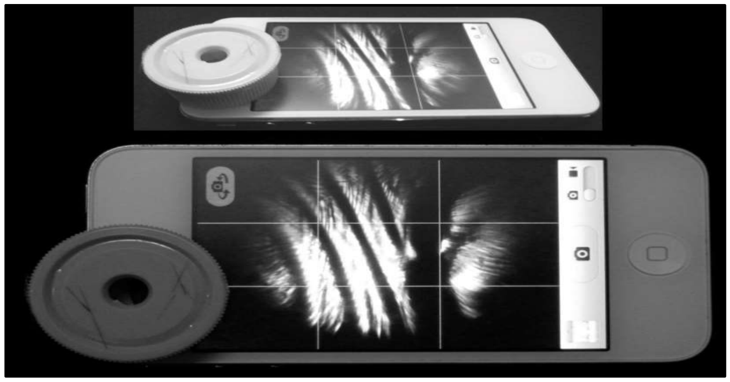

Figure 7. Taking a photo from a microscope using a mobile phone.
*[Source- Photographs taken by the Research Group]*

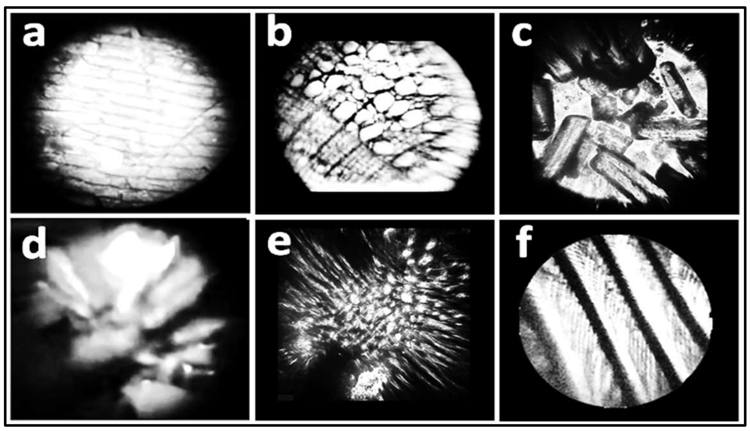


Figure 8. Photos from a microscope taken by a mobile phone.
(a) onion cells, (b) plant stem x-section, (c) crystal of MSG, (d) an insect, (e) corn stem x-section, (f) feather
*[Source- Photographs taken by the Research Group]*

This simple microscope can be used in the classroom or can be used for out-of-school science activities like science project, science camp or even an on-line learning etc. A computer tablet can also be used with this simple microscope to take a picture or a video of a sample in the classroom as shown in the Figures 7 and 8.

In many schools of rural areas, some students have problems with head lice. Head lice are tiny insects, which live in the hair and feed by biting the scalp and sucking blood. The female head louse lays her eggs close to the scalp where it is warm enough to incubate them. Lice are most easily detected by combing really well conditioned soaking wet hair with a fine-tooth comb. Regular head inspections in school, therefore, are of dubious value because only the most severe cases are likely to be detected. Many milder cases will be overlooked, thus lulling parents and schools into a false sense of security. Using this simple microscope, the teacher can arouse curiosity of the students as well as awareness about the hygienic condition of students. Head lice can be clearly seen by this microscope. Figure 9 shows a head louse using a computer tablet to view as well as to take video of a live louse from student's head.

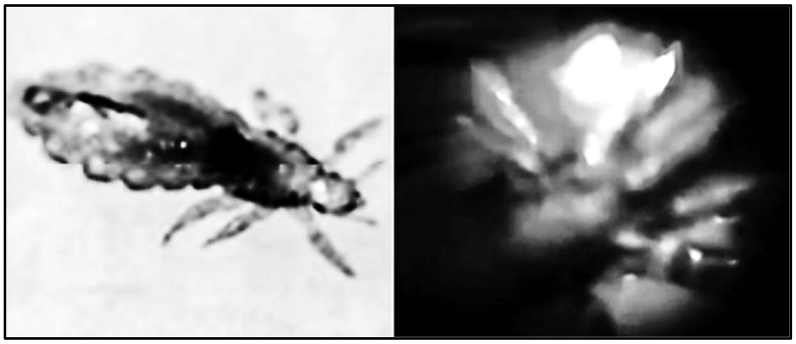

Figure 9. Showing a Louse head. A video of a head louse can also be taken

*[Source- Photographs taken by the Research Group]*

In fact, spherical aberration from a spherical lens cannot be avoided. When a larger size lens is used, a brighter and sharper image is obtained, but the magnification of the larger lens is less than that of a smaller one. The magnifications for lenses of various sizes are given in Table 1. For one who wants to make a lens with a desired magnification, equation (4) is recommended.

Table 1. Magnification for lenses of various sizes.

| Index of Reflexion (n) | Lens Diameter d (mm.) | Focal Length f (mm.) | Magnification M |
|---|---|---|---|
| 1.5 | 2.0 | 1.5 | 167 |
| | 2.5 | 1.9 | 132 |
| | 3.0 | 2.3 | 111 |
| | 3.5 | 2.6 | 95 |

Although the magnification of the lens cannot be accurately controlled. by control of the lens diameter, and spherical aberration cannot be avoided, such a microscope, however, can serve study at high school level quite well. Furthermore, its cost is very cheap compared with a commercial one. The problem of the lack of educational demonstration equipment in a developing country will be met if efforts are made to improvise the necessary equipment when resources do not permit the acquisition of commercial equipment.

A polarizing microscope using two polarizing sheets: the polarizer and the analyzer was applied to view onion cells. The polarizer is placed below the specimen and the analyzer is placed above the lens as shown in Figure 6. Images of onion cells from normal microscope and from polarizing microscope are compared in Figure 10. Image of onion cells from normal microscope looks clear and monotonous but the image from polarizing microscope is colorful. The specimen can be seen over the dark background, and it does not need to be stained.

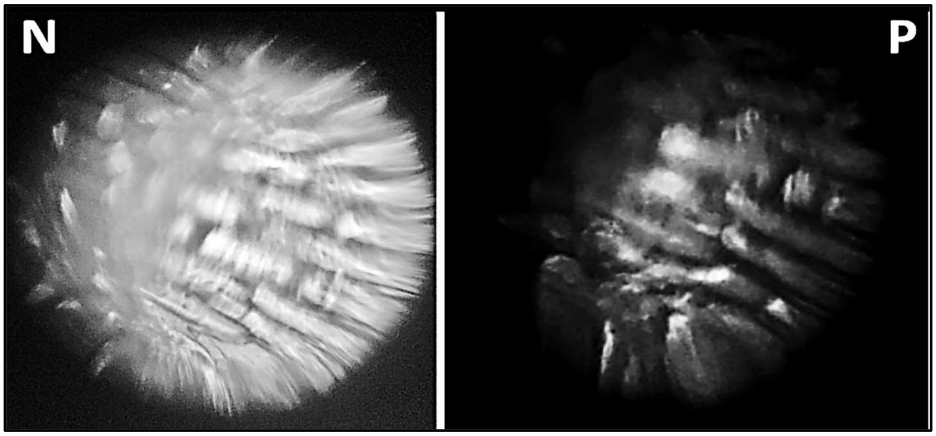


Figure 10. Images of onion cells from normal microscope (N) and from polarizing microscope (P) are compared. *[Source- Photographs taken by the Research Group]*

## 6. Suggestions for Further Study Project:

The problem of this simple microscope is that it cannot be used with wet specimen. Therefore, we would suggest that there should be some study of development of a simple microscope which can be used with wet specimen slides.

Although this simple microscope has been known for a long time, but it has not been widely recommended. Schools should therefore encourage students to try it out for themselves. Teachers may create various activities to expand the effective use of it. Or there may be a competition for various activities using this simple microscope. For effective biology education, students should study and collect specimen from various parts of plants and animals as a data bank for future use.

## 7. Conclusion:

After making a large number of this simple microscope and testing it out in both primary and secondary schools as well as performing activities outside the classroom for science camp, It was found that students enjoyed learning and had a better understanding of biology.

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Web-links

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