Gauging How Widespread Availability of Smart Phone Cameras by Themselves or in Combination with Magnification Devices Can Displace Optical Microscopes in Grade Level Education

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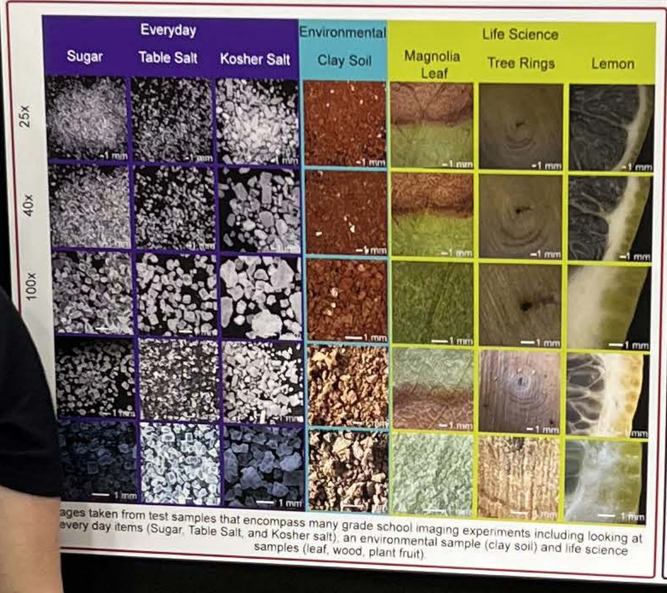
Abstract:
Microscopes have long been a mainstay in early S.T.E.M. education and are often used to show students key aspects of science ranging from environmental and life sciences to first chemistry experiments [1,2]. Unfortunately, the microscopes used are typically legacy systems with limited magnification capabilities, suffer from clunkiness of usage, and there are a low number of microscopes per classroom. *These shortcomings limit the students' inherent learning time with microscopes and greatly reduces the engagement of these students in their core science learning.*

Advantageously, a number of rudimentary magnification devices have entered the learning space that yield an inexpensive and user-friendly method of imaging samples in the classroom. This, along with advancements in mobile phone camera technology, have led to the combination of these devices being feasible substitutes for in-class microscopes, as well as offering a straight forward method of image capturing [3].

We will show the differences between a straight-forward **mobile phone camera** (iPhone 13pro 3x camera), **magnification device/mobile phone combination** (iPhone 13pro and an Echo wood magnification device, 6x magnification in total) and an **optical microscope** (imaging at 25x, 40x, 100x which are common imaging magnifications on grade school microscopes) to cross compare their respective efficacy in standard imaging projects seen in middle school STEM education.



ages taken from test samples that encompass many grade school imaging experiments including looking at every day items (Sugar, Table Salt, and Kosher salt), an environmental sample (clay soil) and life science samples (leaf, wood, plant fruit)

Image of a grade school microscope (A); Echo wood Magnification Device (B); An image of a modern mobile phone in this case an iPhone 13pro (C).

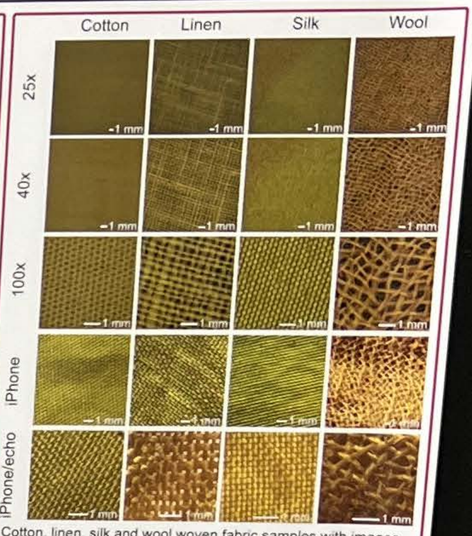
Results:
As will be quickly noted when looking at the everyday samples the listed magnification "x" value, is quite deceiving (a widely known fact in the microscopy community), with the iPhone 3x images more closely resembling images taken at 40x magnification with an optical microscope. When the magnification device is coupled with the mobile phone camera (6x) these results are similar to those of the optical microscope at 100x.

Everyday samples of sugar, table salt and kosher salt we see some surface features such as in a case of the larger kosher salt grains as well as the particle size and shape especially in the cubic table salt samples.

Environmental samples clay soil was viewed, we see a similar ability to see size and shape of the grains that compose the aggregate soil between the different imaging platforms.

Life science samples, we can see the same venous features of the leaf including the veins and venules; wood rings to calculate aging; and the parts of fruit in this case lemon showing good detail of the Albedo and exocarp regions.

Fibers, when we look at the natural dyeing of fibers, a common early chemistry experiment, the dye quality of the turmeric can be seen with the varying colors of yellow being seen on either cotton, linen, silk or wool fibers lots. In these images one short coming of the combination device can be noted in the lack of focal depth with the more topographic fiber mats such as wool. Further, the overall length scale being viewed in the combination device, being very good with students being able to learn about the different fiber diameter sizes and weave types as well as being able to detect variations in the color of the dyed fibers, for example the cotton fibers having the highest level of yellow undertones and silk having the least when their respective CMYK color palates are found, when using the combination devices images for rendering the color.



Cotton, linen, silk and wool woven fabric samples with images taken at 25x, 40x, 100x with a conventional optical light microscope, iPhone and iPhone/Echo combination device.

Conclusions:
- By cross comparing these images it is *clearly evident* that the wide spread utilization of phone cameras especially in conjunction with magnification devices provide an excellent route forward for building a broader learning environment by putting in place a system in which more students have access to imaging.
- Also the widespread smartphone ownership of grade school students means that this set up would be a very accessible option for many middle school classrooms, allowing a more thorough and in-depth introduction to microscopy and scientific analysis at an earlier age.

References:
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