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The Foldscope

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Abstract: Manu Prakash at Stanford University invented the foldscope, two years ago, for use in remote areas to identify disease organisms. The foldscope is an optical microscope composed of paper and a lens and costs 50 cents to manufacture. A pre-service science teacher with her supervising professor used the foldscope for fieldwork at Sandy Hook New Jersey on both the bay and ocean side of this national park. A sampling of both sides of Sandy Hook New Jersey, bay side and ocean side, was done to determine the usability of the foldscope in the field component of coursework and additionally for use in a science classroom.

Key words: microscope, optics

1. Introduction

The foldscope was invented two years ago by Manu Prakash at Stanford University for use in remote areas to identify disease organisms. The foldscope is an optical microscope composed of paper and a lens and costs 50 cents to manufacture. A pre-service science teacher with her supervising professor used the foldscope for fieldwork at Sandy Hook New Jersey on both the bay and ocean side of this national park. A sampling of both sides of Sandy Hook New Jersey including bay side and ocean side was done to determine the usability of the foldscope in the field and perhaps in a classroom.

2. Literature Review

The Prakash Lab team at Stanford University developed a microscope that is folded like origami and contains all of the components of a normal microscope, and is produced for less than $.50; a foldscope. This new technology is believed to have benefits in education, global health, and medicine (Prakash Lab). The foldscope is capable of magnifying over 2,000 times, however because the foldscope is only in Beta testing, the microscopes sent out to global testers will only have 140 times to 480 times magnification. The Prakash Lab has created many specific foldscopes in order to detect certain diseases. In some underdeveloped countries that may not have access to microscopes, the foldscope can be a key diagnostic tool, and can therefore lead to better treatment. In a classroom setting, students can use a foldscope to individually have access to an affordable, lightweight, and durable tool to discover objects under a microscope.

Current light microscopes are useful for understanding organisms in a classroom, but are very expensive to purchase, difficult to take into the field and because of their size require a sizable amount of storage space. Light microscopes are capable of magnification from 40-400x. A foldscope is capable of similar magnification, is easier

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to store, cheaper to manufacture and therefore more affordable for school districts. In addition, foldscopes are ideal for use in the field because they are made of silicone-covered paper, which makes them waterproof and durable. In the classroom, foldscopes are capable of projection in a dark classroom, with the use of a flashlight and syncing with smartphones for taking photos of the objects viewed by the foldscope.

Light microscopes are an invaluable tool in the classroom, but are problematic for fieldwork. Foldscopes can be more easily managed forfieldwork with students. Light microscopes require instruction on how to transport and how to use in the field. The foldscope can travel with the students in their backpack with minimal instruction or worry of destruction. Foldscopes allow for self-discovery learning, which promotes inquiry in the field (Garzon, Ingrid et al., 2015). The foldscope technology that is available to students allows more use of technology both inside and outside the classroom that is helpful for learning. The foldscope also easily interfaces with smartphone use.

3. A Brief History of the Microscope for Classroom Use

Robert Hooke and Jan Swammerdam were tinkering with microscopes and they are named inventors of the first compound microscopes. Although Hooke and Swammerdam invented microscopes that resemble today's compound microscopes, they were only able to magnify 20-30 times the size of the organism. Anton van Leeuwenhoek is called the father of microscopy. He made many discoveries looking at sperm cells, blood cells, and protists, and also was an inventor of over five hundred microscopes. Many of his microscopes relied on magnifying lenses, but none resemble what our compound microscopes look like today. Leeuwenhoek's many microscope models enabled him to perfect a few that could magnify over 200 times (Waggoner, 2006).

Leeuwenhoek could see specimens in more detail than his predecessors, and he was able to record his observations much more accurately (Waggoner, 2006). Leeuwenhoek attended to details very efficiently, and he also was an illustrator. These two traits helped him to record observations in the form of a picture in addition to written words. Leeuwenhoek had a great curiosity to magnify the world that lived around him, he sampled pond water just to see what was in it, he sampled tartar from his teeth and from many other peoples teeth, and went on to describe the small "animalcules" inside of the tartar (Waggoner, 2006).

Leeuwenhoek's curiosity was a passion similar to that of a child's. These curiosities to observe, touch, smell, and feel the world around us is innately beneficial in a science classroom. This curiosity is exactly what a teacher should preserve and develop in students, to get them interested in a topic. A science teacher using the foldscope can allow for students to individually get a microscope and fulfill the curiosities that many of them have about what exactly is in pond water, or how tartar looks under a microscope to record their own observations.

The development and perfection of the microscope didn't stop with Leeuwenhoek, and still has not stopped today. According to The Nobel Prize website once the compound microscope was perfected, it became mainstream for scientists to use them. Subsequently, complex microscopes were developed. The phase contrast microscope was a major discovery for observing biological organisms because it could view colorless materials. Then the development of the electron microscope improved the amount of detail that could be viewed. The advent of the scanning tunneling microscope allowed for the three dimensional view of materials (AB, 2015). Today we have the advent of many computerized microscopes that can help students view materials using an App on an iPad and a handheld magnifying device. The foldscope is the most recent invention that can be used with these Apps.

Today we have simple microscopes, and more commonly compound microscopes in the classroom.

Increasing technology increases the usability of microscopes even more through iPad's Apps. For example, according to Pacific University, the ProScope is one of the technologies that can be used in a classroom for students to get real time microscopic images on an iPad. The ProScope is very portable, and allows for students to work in small groups, or individually to view objects under the microscope. While this microscope doesn't look like the usual microscope, and looks more like a small hairdryer, it is very easy for students of all ages to use (Pacific University, 2014).

A professor at Monmouth University received the foldscopes with the goal of developing lesson plans to implement in elementary, middle, and high school grade levels. Once the foldscopes were received and assembled it was the objective to eventually test these developed lessons in a functioning classroom and in the field. Foldscopes seem to be affordable, portable, and durable indicating extensive usage by students. For example, students may be able to take them home in order to observe things that they are curious about. Teachers may be able to afford and store many more foldscopes compared to the usual compound microscope, allowing each student to have better access to the foldscopes. The goal was to capture the curiosity that students naturally have, and foldscopes may allow teachers to do that.

3.1 Purpose of the Study

The purpose of this study was to identify and describe how students and teachers respond to and are able to effectively use foldscopes.

3.2 Research Question

What happens when teachers and students use foldscopes? Are they effective tools for students to use? How well do teachers adapt to this new form of technology?

3.3 Research Method

This is a traditional qualitative research study. Three sources of data were collected. The sources of data include, observations of the teachers and students learning to use the foldscope, artifacts in the form of student produced data from the field and interview responses from the teachers.

4. Data about Foldscope

4.1 Teaching Methods

Samples were obtained from Horseshoe Cove (HC) and North Beach (NB) in Sandy Hook National Park (Figure 1). Five sand samples at different sites were (ocean side) (Table 2). Water samples were obtained at various depths to obtain organisms in varied levels in the water. Samples were obtained from the top water, bayfloor, and 1 cm, 3 cm, 5 cm, 7 cm, 10 cm levels from bottom level on both Horseshoe Cove and North Beach. Photos using the 400 power lens of the foldscope were taken of each sample. This procedure was repeated for 6 days and time, date, weather condition, water temperature/pH, site, sample height were recorded (Table 1). The high-powered, 400 power foldscope proved to be best for observing microscopic organisms obtained in the samples in the field. All photographs were then taken back to the lab for further research into identification of the organisms.

Figure 1　Map of Site Locations at Sandy Hook, NJ

Sand samples and water samples were taken from two sites, Horseshoe Cove and North Beach. Horseshoe Cove is located on the bay side of Sandy Hook and North Beach is located on the ocean side of Sandy Hook.

Figure 2　Water Sample Site Location at North Beach and Horseshoe Cove

4.2 Student Collected Data

Water samples were obtained from Sandy Hook's North Beach (NB) and Horseshoe Cove (HC). The date, time, weather condition, water temperature and pH, site, height from the bottom, and the organisms observed were recorded. A foldscope was used to observe all samples in the field, and the foldscope was synced to a smartphone to photograph all samples. The pH was recorded using a digital pH reader. The water temperature was recorded using a traditional glass thermometer.

Table 1 Water Samples

Date	Time	Weather Condition	Water Temperature/pH	Site	Height from Bottom	Organisms Observed
6/22/15	13:30	Sunny	NR	NB	10 cm	0
6/22/15	14:00	Sunny	NR	HC	10 cm	0
6/25/15	11:30	Partly Cloudy	NR	HC	3 cm	Cyanobacteria
6/25/15	11:30	Partly Cloudy	NR	HC	1 cm	Cyanobacteria/Diatoms
6/25/15	11:30	Partly Cloudy	NR	NB	3 cm	Cyanobacteria/Diatoms
7/8/15	11:30	Cloudy	28°C/8.05	HC	top water	Cyanobacteria/Diatoms
7/8/15	12:15	Cloudy	26°C/7.70	NB	top water	Cyanobacteria/Diatoms
7/10/15	11:15	Sunny	30°C/7.28	HC	Bayfloor	Cyanobacteria/Diatoms
7/10/15	11:45	Sunny	28°C/7.75	NB	Seafloor	Cyanobacteria/Diatoms
7/21/15	10:00	Partly Cloudy	30°C/8.06	HC	7 cm	Cyanobacteria/Diatoms
7/21/15	10:30	Partly Cloudy	28°C/7.79	NB	7 cm	Cyanobacteria/Diatoms
7/23/15	11:45	Sunny	27°C/8.27	HC	5 cm	Cyanobacteria/Diatoms
7/23/15	12:15	Sunny	26.5°C/7.92	NB	5 cm	Cyanobacteria/Diatoms

Figure 3 Sand Sample Site Location at North Beach and Horseshoe Cove

Sand samples were collected on 06-22-2015 at both NB and HC. Five sand samples were collected at random in small plastic Ziploc bags, and labeled with the sample site and a number 1-5. Sand Samples were observed using the Foldscope, and photographed.

Sand samples were obtained once on 6-22-15 at five random locations at NB and HC. The time, description of day, site and depth of the sand sample were recorded. All sand samples were later observed and photographed using a Foldscope, magnetic smartphone attachment, and an iPhone.

Table 2 Sand Samples

Date	Time	Description of Day	Site	Depth
6/22/15	13:30	Sunny	NB	Surface
6/22/15	13:30	Sunny	NB	Surface
6/22/15	13:30	Sunny	NB	Surface
6/22/15	13:30	Sunny	NB	Surface
6/22/15	13:30	Sunny	NB	Surface
6/22/15	14:00	Sunny	HC	Surface
6/22/15	14:00	Sunny	HC	Surface
6/22/15	14:00	Sunny	HC	Surface
6/22/15	14:00	Sunny	HC	Surface
6/22/15	14:00	Sunny	HC	Surface

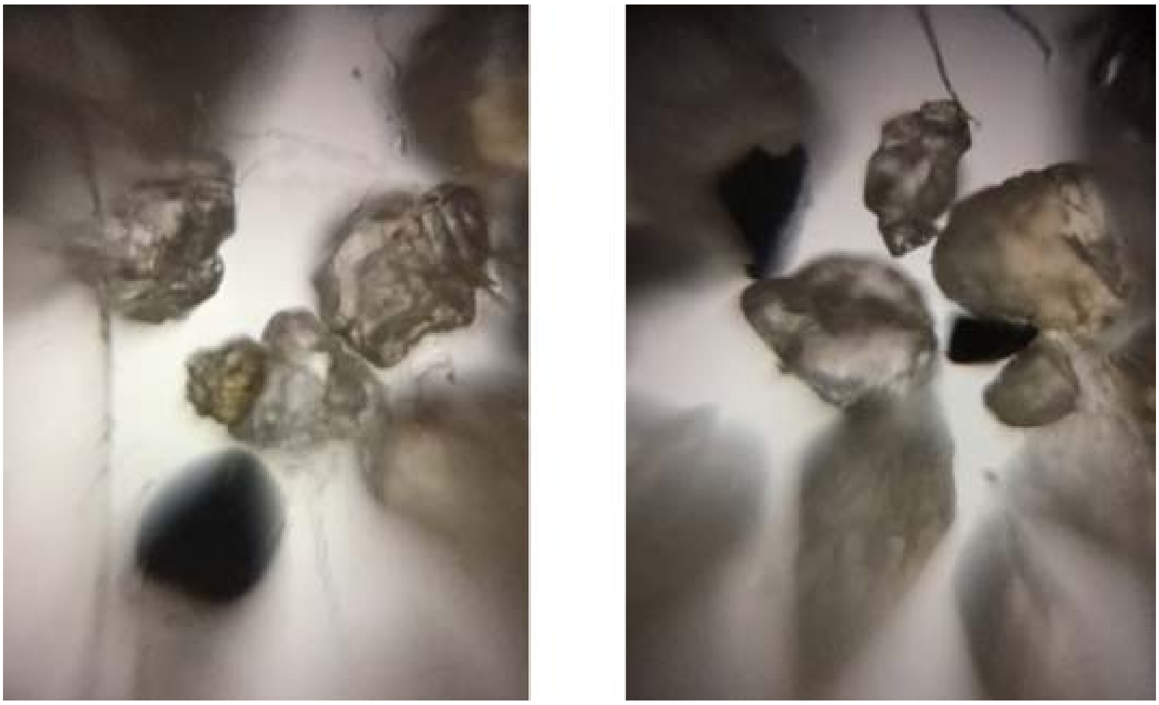

Figure 4 Sand Sample Photographs Using a Foldscope and Smartphone

Using a Foldscope, magnetic smartphone attachment, and an iPhone two pictures were taken of each sample. The pictures shown above were taken from the sample NB1.

Photographs were then taken back to the lab for further identification of the organisms.

4.3 Lessons Revealed Based on the Three Sources of Data

4.3.1 Students were able to collect samples and collect pictures of their findings.

Students were observed collecting samples and using SmartPhones to store images of sand and organisms from the field studies. The teachers noted that students were very adept at completing the interface between the phone and the foldscope. The artifacts, in the form of the pictures above reveal the ability of the students to use this technology. When the teachers were interviewed it was clear that they had also gained the ability to use the foldscopes and interface them with the smartphone and apps because they were able to describe the process and assist their students to do the same. Both the teachers and students were able to generate clear pictures of the organisms.

The Foldscope itself is very pliable, because it is made out of paper, which allows for the user to focus the sample by pushing and pulling on the focusing tabs. It was very easy to observe a sand sample while looking through the Foldscope lens, but sometimes focusing the sand sample was difficult while trying to take a picture with a smartphone. Taking a picture using a foldscope was definitely easier than taking a picture with a traditional light microscope. Observing the water sample was effortless both with and without a smartphone. Taking a picture with the water sample was more difficult due to the unsteady movement in the field. Instead of taking one picture of the water sample, it was much easier to take a video. This allowed for both hands to be on the Foldscope to focus the sample, without needing to press any buttons on the smartphone. Taking a video also made it much easier to look at other areas of the sample and focus them, without having to take multiple pictures.

4.3.2 Students were able to easily transport and not break the foldscopes.

The students were able to place the foldscopes in their notebooks and carry them to the field sites. There were no needs for additional storage space in the buses for the foldscopes and thus smaller buses could be used for the trip. No students needed assistance to carry the foldscopes because they are very lightweight. Finally, no foldscope was lost nor broken during the field visits.

4.3.3 The teacher will be able to afford the foldscopes in the future with regular classroom funds.

The foldscopes will cost approximately $.50 when they become available. Thus, teachers would be able to afford many foldscopes in contrast to the high expense of other forms of microscopes.

5. Discussion

The Foldscope was discerned to be a useful tool for preliminary analysis of the water samples and for identification of water organisms by students on field visits. The magnification of the high-powered foldscope did not reveal as many details as a traditional light microscope on a high magnification. However, the foldscope functioned well in the field by being easily transported with no concerns to weather conditions or to concerns about breakage. It was useful for observing the sand samples, as details of the sand were very easily observed.

Using the smartphone attachment made it very easy to document the sand samples and the water samples.

The uses for a Foldscope in a classroom are endless. Learning how to use the foldscope is simple because once the Foldscope is assembled there are only a few things that need to be taught to students. Specifically the student needs to know where the lens is, where to put a slide, and how to focus the sample. All of these things can be explained to students of all ages. As an increasing number of students have access to smartphones, they can document the samples that they observe. This allows for teachers to assess the work that students are doing by having the students send their pictures to the teacher. Students can also share the pictures that they take with their peers. This may increase a dialogue between students which may lead to a greater comprehension of the material.

6. Conclusion

Overall, using the foldscope in the field for analysis of both sand and water samples was valuable. The foldscope travels easily, works well and is easily synced with smart phones for photographs of the organisms observed. Breakage and storage is no problem when using the foldscope.

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