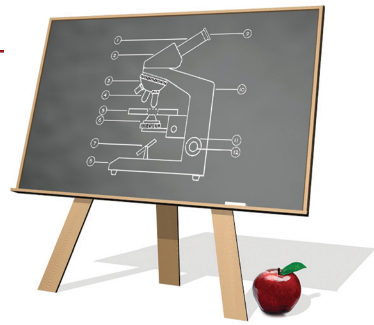
MicroscopyEducation

When Specimen Choice Wags the Microscopy Education Dog



Mark Armitage
DSTRI, Inc. 325 East Washington Street, #170, Sequim, WA 98382

profmark@dstri.org

Abstract: The use of microscope technology has proved to be foundational in the global advancement of science and medicine. However, fewer women are entering science and microscopy as a career. Many factors have been suggested for this decades-old trend, yet intense mentoring of female students by successful women in academia and industry may be reversing the trend. Our team designed a STEM microscopy curriculum in a mobile laboratory format to test the idea that more female students might show an interest in STEM training if they have a chance to operate a microscope. The interest in dinosaur remains is very high among secondary students, thus we reasoned that choosing dinosaur tissue remains as a specimen might attract such students to hands-on labs. Here we describe our efforts to attract female students to microscopy-related STEM content by using dinosaur soft tissue from our dinosaur digs as specimens during our hands-on microscope labs. We conducted 33 such labs in six states across the US over a 16-month period. Female student participation was over 52%. We suggest that the specimen choice (particularly dinosaur cells, veins, and nerves) in microscopy education provides a powerful incentive to female students to consider a science as a career.

Keywords: dinosaurs, STEM education, microscopy, females

Introduction

No one would dispute today that the microscope as a scientific tool has revolutionized science and our understanding of the world, especially the world unavailable to the naked eye. The hallways of scientific achievement include the names of important scientists who employed microscopy and advanced its development while advancing human knowledge. Lister, Pasteur, Koch, Mayo, and Virchow come to mind. Human health and longevity are much improved as a result of the influence of the microscope, particularly within medicine. Microscopes configured to various illumination, magnification, and imaging options are used worldwide daily to analyze everything from ant sensors to zebra blood. My personal favorite among microscope applications took form in the late 1980s when working for Reichert-Austria. This involved a refitting of the well-known Reichert Polyvar microscope with calcite optics to allow infrared imaging of silicon semiconductors. Binocular tubes and eyepieces were eliminated, as infrared cameras provided the only images. Silicon proved to be transparent to this instrument, thus both sides of chips could be imaged simultaneously for verification of critical alignment front to back. It was expensive to build and install, and a costly lesson for the chip manufacturer when the new tool began rejecting computer chips due to irreparable misalignment.

My career in microscopy proved exciting and rewarding, yet one thing continues to disappoint. Fewer students seem interested in STEM training and in science as a career today, most notably females [1–10]. Intimidation by their male counterparts, lack of recognition for work done, and other factors have been cited as reasons for this, but intense mentoring of female students by successful women scientists, along with increased recognition of their work in microscopy, might be helping [2,5,9].

During the decade following 1985, I was part of a small team that offered and conducted hands-on microscope workshops across the Southwest. The objective was to simply introduce high school students to microscopy using college-level instruments, in hopes of encouraging them to pursue an academic career in science. Samples prepared for student examination were chosen from common household items that humans encounter routinely. We settled on items that provide compelling images for dissecting and compound microscopy. Students were keen to observe comparisons between salt and sugar, pepper and tobacco, Cheerios and shredded wheat, and sparkling toothpaste and body glitter under compound and dissecting microscopes. A student favorite was to observe the vast numbers of swimming oral bacteria present in tongue cell scrapings imaged on a dark-field microscope. In spite of the excitement generated, no students attending those labs expressed an interest in a scientific career or ever contacted us for more information. Post-lab mentoring was unavailable at that time, which may have contributed to lack of interest.

In November 2021, the Dinosaur Soft Tissue Research Institute (DSTRI.org) launched an initiative to procure new dissecting and compound microscopes, illuminators, cameras, and polarized light accessories with the intention of preparing a mobile microscope laboratory that could be delivered to sites around the country for instructional purposes. Our plan was to offer a college-level hands-on microscope lab experience to private school students to generate interest in a career in microscopy. We capitalized on the fact that many middle and high school students are fascinated by dinosaur fossils (especially teeth and claws) and that any examination of them, especially with microscopes, might be of intense interest (Figure 1). We also realized, through our own laboratory work on dinosaur tissue extraction, that a plentiful supply of cell, vessel, and nerve specimens for laboratory instruction could be supplied. Our work had demonstrated that such tissues were easily harvested from our dig-site fossils, therefore stable, permanent mounts for examination by students became a reality.

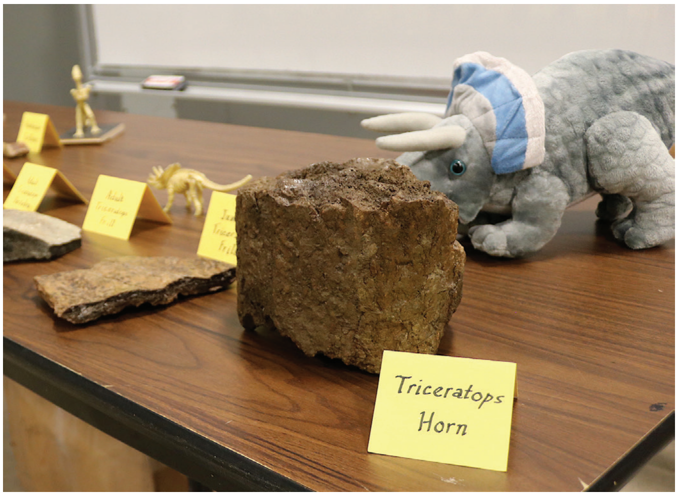


Figure 1: Table of gross dinosaur bones that students could handle and examine.

During the 14 months of this project, we conducted 33 hands-on dinosaur bone microscope labs at private schools in six states across the US.

Materials and Methods

We procured 10 Luxeo zoom stereo dissecting microscopes and 10 CXL compound microscopes from Labo America, Fremont, California. Dual gooseneck fiber-optic illuminators were chosen for oblique illumination use on dissecting microscopes, and the binocular compound microscopes were fitted with polarizers and analyzers for identification of birefringent nerve fibers. Compound microscopes were outfitted with 4×, 10×, 40×, and 60× dry objectives. Some instruments were obtained in a trinocular configuration, with attached cameras to facilitate student photography during labs. We decalcified dinosaur bones and collected cells, vessels, and nerves for permanent slides. Slides known to contain cells, vessels, and/or nerves were marked with circles and other fiducials on the glass for students to follow to locate objects of interest. Other dinosaur bones were thin-sectioned to 40 μm and mounted without coverslip for dissecting and compound examination. Representative pebble-sized shards of bone were also oriented and glued to microscope slides to assist in identification of bone canals, osteons, cells, bone lines of growth, and even clots within canals. Fresh bone material was decalcified, transferred into dialysis bags, and washed repeatedly in distilled water before transport to student labs. This washed, decalcified "bone juice" was used during the lab session as a final exercise. Drops of "bone juice" were pipetted onto slides and coverslipped for immediate student examination.

A PowerPoint lecture was prepared for display during lab sessions so that students were abreast of lab progress, remaining exercises, and expectations. An instructor station was prepared with high-quality research dissecting and compound trinocular microscopes/cameras, and specimen images were displayed on a 45" flat screen TV with HDMI input. The instructor station was used to display images of specific tissues to assist students in recognizing tissues at their own stations. It also proved a valuable tool when certain students were having trouble working at their own microscope station. Personalized instruction helped several students overcome the struggles they had encountered.

A mandatory parent-teacher conference was scheduled in each city before lab sessions were conducted so that parents could gain an understanding of curriculum content and activities planned for their students. These conferences typically lasted 2 to 3 hours, and many questions relating to the dinosaur digs, dinosaur bones, and student expectations were answered. The night before labs began, 5 to 6 adult lab facilitators attended and successfully completed the same lab planned for students, thus they were familiar with what the students were going to experience. The adult lab facilitators were also trained in the types of responses and body language they could expect from students who were reluctant to admit that they were not seeing what they were expected to see. Adult facilitators were also trained in ways to assist students in positioning their hands for proper microscope knob control. Adults were not allowed to use cell phones during labs, but students were excited to collect images of tissues they found with their own cell-phone cameras.

Three-hour student labs were scheduled each lab day, beginning at 9 a.m. and ending at 6:30 p.m. In this way, 60 students could receive instruction per lab day. Students were paired to work together as partners at each microscope station. We chose to pair one tall student with one short student per station, which eliminated unwanted behaviors and actually benefited both partners, as they seemed to be more attentive and productive in finding objects of interest. At several points during the lab students were moved from microscope stations to a separate teaching area for further discussion and instruction using PowerPoint slides.

Each lab began with a safety lecture for parents and students in a room outside of the lab. Emphasis was made on the inherent risks of skin injury due to glass slides, coverslips, pipettes, and solutions of EDTA, as well as dangers associated with loose or baggy sleeves, baseball caps, and backpacks (all are known to topple instruments to the floor). At the conclusion of the safety lecture, students and parents were escorted into the laboratory and parents took photographs of the lab and students for several minutes before all non-students were excused so that the lab sessions could begin. At the conclusion of each lab, students were given the opportunity to collect photos from previous lab specimens and copy them to their own thumb drives. Most students were also allowed to choose individual bone shards from our dig collections to take home with them.

Results

Lab tables were arranged in a U-shape with one set of tables for dissecting microscopes and another set for compound microscopes. The instructor station with the monitor formed the bottom of the U-shape (Figure 2). Students would alternate between microscope use at the microscope tables and instruction in a theater-style setting with PowerPoint instruction (Figures 3a,3b). Students quickly learned to use microscope adjustment knobs without looking away from the eyepieces (Figure 4), especially after performing the introductory hand-eye coordination exercises. They also found

Figure 2: Hands-on dinosaur bone lab in "U-shape" with instructor station at the top.

Figure 4: Students using microscope knobs without looking away from eyepieces.

that they could work well without using their eyeglasses (Figure 5). Two warm-up exercises were designed for the dissecting microscope to engender hand-eye coordination. Students were required to put their eyes up to the eyepieces, and, without looking away, they had to bring a very small nut and bolt together with each hand and assemble them on the stage plate under the microscope (Figures 4–5). Next, students had to repeat the exercise with the smallest needle and thread combination we could find. Both exercises consumed significant time, but student productivity improved greatly after the exercises.

We averaged 18 to 20 students per lab session (total attendees was 614), and some labs had more than 20 students. Surprisingly, female student attendance often exceeded male attendance. Overall female attendance was 53%. Females were frequently first to complete exercises, answer questions, and announce they had found tissues such as cells and nerves when asked to find them. No students were ever

a

b

Figure 3a, 3b: Theatre-style teaching area with projector and screen.

Figure 5: Students learned that they could work more efficiently without eyeglasses.

a
b
c


Figure 6a–6c: Students using microscope knobs without looking away from eyepieces.

excused from labs for disruptive behavior, and no students failed to complete the lab. During labs, students spent considerable time working quietly with specimens under the microscope and often seemed reluctant to relinquish the microscope station to their partner when asked. We assessed student sentiments and impressions during discussions in the theater-style area, particularly near the end of labs. Most students expressed excitement and wonder at what they had observed. Many stayed after the end of lab to have us autograph the free books we gave to each student. Interestingly, during assessment discussions in each lab, students were asked to raise their hands if they felt that lab was "not their cup of tea." Most labs had at least 3–4 students who agreed with that sentiment, yet their excitement in the lab remained undiminished.

Discussion and Conclusions

Every lab session we conducted was filled or nearly filled, clearly an indication that interest in microscopy of dinosaur tissues was high. In one of the six cities we visited, student registrations just prior to labs were low; therefore, we asked and were allowed to address about 100 students over three days at private schools, which promptly boosted lab registrations. We were also surprised by the large turnouts at the parent-teacher meetings. Often, entire families attended, and many younger siblings asked incisive questions indicating high interest. At several of these meetings we asked for a show of hands from those who desired to take the lab, and most family members, including parents, raised their hands. We are presently in contact with 5 students who completed our lab and who continue to work on their own in this field of study. Three students have returned to serve as adult lab facilitators at lab sessions conducted outside their own city or have conducted teaching sessions on their own where they live, using their own microscopes. One student paid her own expenses to serve on a dig with us over several days in Montana. We conclude that our choice of dinosaur tissues as specimens for our hands-on labs has generated a high level of interest in microscopy training, has increased enrollment among private school families when compared to previous lab experiences, and has produced students who desire a career in science.

References

[1] C Queenan et al., *Microscopy Today* 19 (2011) https://doi.org/10.1017/S155192951100037X.

[2] R Ceglie, *Intl J Sci Math Educ* (2021) https://doi.org/10.1007/s10763-020-10090-w.

[3] C Cowgill et al., *Psychol Women Qtrly* (2021) https://doi.org/10.1177/0361684320965123.

[4] S Moshfeghyeganeh and Z Hazari, *Phys Rev Phys Educ Res* (2021) https://doi.org/10.1103/PhysRevPhysEducRes.17.010114.

[5] C O'Connell and M McKinnon, *Societies* (2021) https://doi.org/10.3390/soc11020027.

[6] S Stewart-Williams and LG Halsey, *Euro J Personality* (2021) https://doi.org/10.1177/0890207020962326.

[7] X Jiang, *Labour Econ* (2021) https://doi.org/10.1016/j.labeco.2021.101991.

[8] X Yang and C Gao, *Res Sci Educ* (2021) https://doi.org/10.1007/s11165-019-9833-0.

[9] MB Ross et al., *Nature* (2022) https://doi.org/10.1038/s41586-022-04966-w.

[10] JW Tom et al., *J Chem Educ* (2022) https://doi.org/10.1021/acs.jchemed.1c00335.

MT