Examples of Optics and Astronomy Related Activities for K-12 Teachers

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Abstract: We present examples of optics and astronomy related activities and demos presented to K-12 teachers. These are simple, inexpensive, and readily available, developed based on the standards of learning to reinforce concepts in the curriculum.

1. Introduction

We present examples of optics and astronomy activities presented to teachers in K-12. Virginia Military Institute (VMI) offers STEM education conference [1]. Teachers from the region attend and participate in presentations, hands-on activities, workshops, and, in addition, acquire Continuing Education Credits (CEU). The conference provides a variety of STEM topics, such as, astronomy, physical science, 3D printing, circuit boards, novel technologies and software. Kinesthetic learning has been demonstrated to be beneficial in assimilating and understanding new concepts [2]. Teachers prefer topics and easy to implement activities they can "take away" and readily incorporate in their classroom instruction while at the same time include easy, inexpensive, and safely handled components. To further help teachers, most presentations aim to be consistent with Virginia Department of Education Standards of Learning (SOL) [3]. The workshops usually include approximately twelve to eighteen teachers for which stations are set up for the demos.

2. Astronomy

Astronomical activities at the K-12 level should naturally reinforce the learning outcomes set forth in the Standards of Learning prescribed by each state. For example, in the Commonwealth of Virginia, the Department of Education's standards of learning for Earth Science [4] lists learning outcomes that focus on the Earth, the solar system, stars, and galaxies. The document also expects students to be active participants in the learning process, requiring them to "do as a scientist does" using technology that is ""transparent" unless it is the focus of instruction [4]." Therefore, it is incumbent upon the teachers to provide instructions on the use of astronomical instruments and software that lets students become active learners, essentially becoming researchers doing what scientists actually do. Consequently, to aid those unfamiliar with astronomical equipment and software, we provide the following examples of how astronomical equipment and software can be used together to enhance a student's learning experience.

2.1. Observing the night sky with binoculars

While binoculars are ubiquitous and inexpensive items for any school's budget, knowing how to best use them for astronomical observations is important. With the advantages of being portable, easy to use, and durable, their two major drawbacks are low magnification and no mount to support them. Coupled with the fact that unless you know where to look, observing sessions can spiral out of control with student scanning the night sky for fun but without really learning. Therefore, investing in a good-quality pair of binoculars (e.g. Celestron's Cometron, 7 x 50) [5] the Orion 5376 Paragon-Plus Binocular Mount with Tripod [6] and the free software program Stellarium [7], teachers can provide a meaningful night exploring star clusters, the Moon, Jupiter, Saturn, and galaxies. Parameters can be set so that Stellarium provides a view of the night sky from any location and the program has enough features to let students have an up-close and informative view of the objects they are observing. The versatility of the Paragon-Plus Binocular Mount lets students of different stature have a turn looking through the binoculars without the need to relocate the object in the binocular's field of view. Binoculars easily reveal the features on the Moon, Jupiter's bands and its Galilean moons, and Saturn, whose rings usually appear small but noticeable. Suitable and easy to find deep sky objects are M13, a bright globular cluster in the constellation of Hercules, the beautiful open cluster M29 in the constellation of Cygnus, and the M31, our neighbor the Andromeda galaxy.

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2.2. Observing the night sky with a small telescope

A portable telescope with quality optics that is easy to use and has a sturdy mount is essential for any serious observations. The typical advice offered is to purchase a Dobsonian telescope, preferably with an 8-inch mirror. Low to the ground, a sturdy mount, and highly portable, this low-cost telescope is an excellent choice for the beginning amateur astronomer. However, unless the object is easily noticeable in the sky (e.g. the Moon), time spent trying to locate unfamiliar objects cannot only be frustrating but valuable observing time is wasted. A small portable computerized telescope (e.g. the Orion StarSeeker IV 127 mm Go To Mak-Cass) [6] telescope is a better choice in a teaching environment. Such telescopes that are Wi-Fi enabled can be controlled by a smartphone or tablet. After a simple alignment, these telescopes locate and track on objects selected from an appropriate software program. Time is then spent observing objects rather than trying to find them. This allows for more options in teaching and more students observing.

3. Optics

One of the learning outcomes for physics in the "2018 Virginia Science Standards of Learning Curriculum Framework" [8] specifies:

> *PH.6 The student will investigate and understand, through mathematical and experimental processes, that optical systems form a variety of images. Key ideas include*
> *a) the laws of reflection and refraction describe light behavior; and*
> b) *ray diagrams model light as it travels through different media.*

Activities for optics presented to teachers and that support this learning outcome include various topics: reflection (plane and spherical mirrors, floating object, multiple reflections, large spherical mirrors), refraction (transparent water tank and laser beam, invisible beads), diffraction, polarized light, and plasma ball, to name a few. A few examples that are discussed in this summary below are well aligned with the requirements of the standards of learning.

Multiple Reflections. Two inexpensive (approximately $1.00) 8"x10" mirrors are positioned with one of the long sides touching. Reflection and virtual image are discussed. The number of virtual images can be changed by varying the angle between the mirrors. Various objects or printouts can be placed in front of one mirror. This can be used to demonstrate how multiple reflections allows for printed matter to be read in reflection and to illustrate the difference between how we see ourselves in the mirror versus how people see us when they face us. As an application, it is useful to refer to markings on emergency vehicles and explain why the words AMBULANCE or EMERGENCY are marked "backwards" and how reflection allows us to read objects placed behind us.

Infinity Mirror: Use same two mirrors as above, now held parallel to each other facing their reflecting sides, one placed in front of the person and one behind. This allows to achieve infinite reflections.

Laser and Fluorescence: While this demo uses somewhat more expensive items (laser pointers) it can be used for several demonstrations. A variety of laser pointers, red, green, or violet, are available commercially [9], with red being less expensive. Simpler concepts, such as wavelength, directionality of a laser beam, reflection, total internal reflection, scattering or absorption can be illustrated with either of these pointers. More advanced topics include fluorescence, applications of fluorescence and of lasers, eye safety and sensor protection. One such activity that, in addition to total internal reflection, illustrates applications of laser and fluorescence includes a bottle of plain water, one of tonic water, and a violet laser. The violet laser beam cannot be seen as it propagates in the container with plain water but is easily seen as a blue beam in the bottle with tonic water due to the fluorescence of quinine in tonic water [10,11].

Besides these examples, the presentation includes more straightforward demos, hands-on activities, and in-house developed short labs, along with specific instructions and available sources.

4. References

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[3] https://www.doe.virginia.gov/testing/sol/standards_docs/science/#2010

[4] Virginia DOE Standards of Learning document, "Earth Science Standards of Learning for Virginia Public Schools – January 2010"

[5] www.celestron.com

[6] www.telescope.com

[7] www.stellarium.org

[8] https://www.doe.virginia.gov/testing/sol/standards_docs/science/2018/index.shtml

[9] Various vendors sell laser pointers. For example, see Arbor Scientific https://www.arborsci.com/collections/lasers.

[10] J. E. O'Reilly, "Fluorescence Experiments with Quinine", Journal of Chemical Education, **52**, 9, 610-612 (1975).

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