Successfully using optical components and systems in novel ways during educational outreach programs for K-12 grades

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Abstract

Much work has been done in efforts to reach students in the K-12 grades to encourage them to learn about optics and related sciences and technologies. One goal of these efforts is to develop the future optical scientists and engineers to carry on the work of this and related societies. One main obstacle is to create low costs novel and effective hands-on optical components and systems for these students to use and from which to get excited.

Students at different grade levels and abilities are receptive to different kinds of components and systems and this must be taken into account when preparing for outreach programs. There are, however, some guiding principles which can be used throughout the various levels, including making sure the components and systems are good examples and not marginal. Small telescopes or microscopes that use poor quality optics which provide poor quality images do more to discourage young students from going into the sciences than if they never had the experience at all.

Some examples of both poor and good quality optical components and systems that will be described and demonstrated include: lenses, telescopes, microscopes, diffraction gratings, Kaleidoscopes, Fresnel Lenses, polarization filters and liquid crystals. The figures in this paper are in color and best viewed on-line or printed with a good color printer.

Keywords: Novel K-12 optics education, informal outreach, hands-on optics, optics demonstrations, low cost components and systems

1. INTRODUCTION

The Optics Institute of Southern California was founded to focus on informal science educational outreach to K-12 grades students. Our goal is to enlist teachers, parents and others involved to encourage these students to be excited about science by using optical components and systems with hands-on visual experiences. When these experiences provide excellent images that are easy to see, then the users want more; if these components and systems do not impress the users right away, their attention tends to wander quickly.

Another concept that reinforces the lessons in the students' minds is assembling optical components into a system. This tends to enable the students to retain the information and experiences. Also, if the students are able to take these components and systems home with them and share them with their friends and family, the experiences are further retained and transferred to others. This then creates young optics ambassadors who can help make science and optics 'cool' at school and in the neighborhoods.

The components and systems described here include: simple lenses, both glass and plastic, simple two lens refracting telescopes, small student microscopes, kaleidoscopes, Fresnel lenses, polarization filters, cholesteric liquid crystals, diffraction gratings and spectroscopes.

2. SIMPLE LENSES AND TELESCOPES

Comparing various quality educational optics components and systems used in the past and present helped us understand the problem and encouraged us to use higher quality novel optical components and systems. To begin with, we looked at the standard plastic injection molded magnifying glass, an example of which is seen here in Figure 1 magnifying a mineral sample.

Figure 1. Plastic injection molded magnifying glass.

Figure 2. Simple low cost refracting telescope.

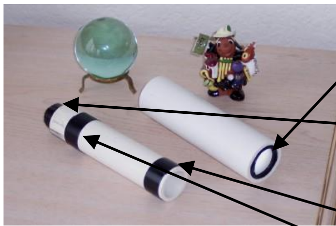
This type of simple low cost optical component seems to do no harm, however it quickly leads us to the next level where a second lens is added to this first one to make a simple refracting telescope as shown in Figure 2. Again, this optical system seems to function as a reasonable low cost teaching tool, however, upon closer examination and use in the classroom, users may come to realize that due to a number of reasons including optical aberrations and opto-mechanical alignment issues it may result is less than impressive images as an optical introduction to teachers and young students.

An alternative refractive telescope system starts with a small glass lens that has the capability to magnify the colored dots on a page printed from a color laser (or equivalent) printer. This optical component and novel application, shown in Figure 3 has been successfully introduced into the Optics Institute of Southern California's (OISC) Optricks Suitcase to teach about printing with colored dots. During a summer program at the University of California Irvine (UCI) Center for Educational Partnership (CFEP) Gifted Student Lower Academy (GSLA) Exploratorium, students were then asked to paint by colored dots on rocks; an example of which is shown in Figure 4. This then brought the concept home for the students and the teachers who were also new to these concepts.

Figure 3. A Lens magnifies colored dots.

Figure 4. Student displaying rock painted with colored dots.

Bringing a second higher quality glass lens to be paired with the first in a fundamentally rigid opto-mechanical system (PVC tubes and electrical tape) as shown in Figures 5 and 6 completes a refracting telescope that can produce optical images that 'Pop' out at users just beginning and advanced to provide experiences that excite the user to continue on to more complex optical components and systems.



One glass objective lens wrapped with black electric tape wedged into the PVC tube.

A second glass eyepiece lens wrapped with black electric tape wedged into the second PVC tube.

Electric tape acts as the friction between the two PVC tubes to keep the telescope focused.

The glass sphere and ceramic figure are for size reference only.

Figure 5. Partially assembled refracting telescope using glass lenses and PVC tubes.

Figure 6. Fully assembled refracting telescope using glass lenses and PVC tubes.

Two advanced users are shown in Figure 7 at a Hands-On Optics (HOO) training session in Southern California comparing the image quality of these two optical systems. Figure 8 shows the first young middle school student at a UCI CFEP GSA Astronomy class complete here telescope as other students look on. The next evening at a Star Party, a young student and his father set up his home made refracting telescope on a very small camera tripod and look at the moon, stars and planets; as shown in Figure 9. Another simple extension of this concept is to mount a simple, but good quality pair of binoculars on a camera tripod, as shown in Figure 10. This can provide a wide field of view and a stable opto-mechanical platform for new users.

Figure 7. Two advanced users compare the image quality of two different refracting telescopes.

Figure 8. The first telescope is completed by a student.

Figure 9. A classroom made telescope is used during a star party on a small camera tripod.

Figure 10. A good quality pair of binoculars mounted on a camera tripod.

3. MICROSCOPES

The next optical system to review is the microscope. It seems that there are many "student" systems available on the market and they can have varying degrees of impact on the students' excitement about continuing their adventures in science and using optics and optical systems. Figure 11 shows a 'student' microscope that may have stressed cost, form and cosmetic design above function. The 'student' microscope shown in Figure 12 looks like it may have better function, particularly since it comes complete with a professional looking carrying case. However, this too may have 'focused' more on appearance than on optical image quality. An example from a new family of microscopes from Vision Engineering is shown in Figure 13; where it was available for Hands-On use by visitors at the Optricks Days event at the Discovery Science Center (DCS). The details of this system is beyond the scope of this paper, however it is based on a patented 'eyepieceless' optical design that makes images 'pop' out at the users. This clearly makes the optical experience unique and satisfying and encourages the users to continue on in science and hopefully optics.

Figure 11. A low quality plastic 'student' microscope.

Figure 12. A mid quality metal and glass 'student' microscope.

Figure 13. High quality 'eyepieceless' microscopes at the Optricks Days at the DSC.

4. KALEIDSCOPES

Another novel optical system that can be very useful when experimenting with flat mirrors is the Three Mirror Kaleidoscope; a diagram of which is shown in Figure 14. Here, three inexpensive long flat plastic mirrors are assembled in a tube with an entrance aperture at one end and a small tray of colored beads at the other. Figure 15 shows a group of students during a HOO special event, where students were so taken by the activity that more students came by after the event because they had seen their classmates exit with the fascinating instruments that they had made themselves.

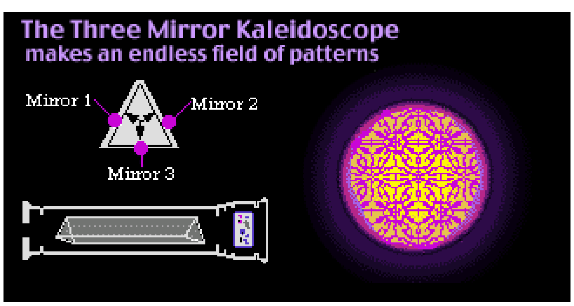


Figure 14. A diagram of a three mirror kaleidoscope.

Figure 15. A group of HOO students with kaleidoscopes they made.

5. FRESNEL LENSES

Large square Fresnel lenses have been successfully used with children and adults as they are encouraged to explore these unusually common optical components. Typically, a Fresnel lens is given to a copy of students and they are asked to look through the lens at each other, as shown in Figure 16. Then, as they giggle and laugh at each others' appearance, and the rest of the students are wondering what they are laughing about, one is asked to turn and face the audience and the result can be seen in Figure 17. Usually a comment is made about scientists being so smart, they sometimes get 'big heads'.

Figure 16. Young students looking at each other through a large Fresnel lens.

Figure 17. A young student looking at the audience through a large Fresnel lens.

6. POLARIZATION FILTERS

Polarization is a fundamental phenomenon well known and understood in the optics community; however, explaining this to students and people of all ages can be quite daunting. A Slinky (as shown in Figure 18) has been successfully employed to introduce the concept of light as waves; water and sound waves are usually briefly discussed. Then the ideas of vertically and horizontally 'polarized' light wave are reviewed.

Figure 18. Young students use a Slinky to demonstrate wave motion.

Figure 19. Young students use an overhead projector, two linear polarizers and plastic utensils to experience polarization.

Typically, when supplies are plentiful, a Magic Stripes Theme Packet, shown in Figure 20, is given to each student to take home and share with family and friends. The linear polarizer is wrapped cylindrically for easy handling by small hands. You can easily see the effects as shown below.

Figure 20. Magic Stripes Theme Packet.

7. CHOLESTIERIC LIQUID CRYSTALS

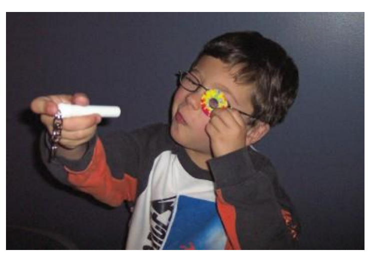
Demonstrating selective reflection in Cholesteric Liquid Crystals is a very low cost effective optical method to get young students involved and interested in science and optics. Popularly known in ‘Mood Rings’, students see the effects and then are asked questions like, “where do the colors come from?” Even older teenagers who have significant self images to keep up, can be enticed by a large LCD on a table, as shown in the photograph Figure 21, taken during a Science Fair in San Diego. Their warm hands leave a multicolor impression on the LCD, as shown in Figure 22 and the experience leaves a lasting impression on their minds. During some presentations, Magic Patches are given to the students as take home theme packets as shown in Figures 23 and 24.

Figures 21 and 22. Teenagers investigating Cholesteric LCDs.

Figures 23 and 24. Magic Patch Take Home Theme Packets.

8. DIFFRACTION GRATINGS AND SPECTROSCOPES

Diffraction is another fundamental optical phenomenon that is quite easy to get and keep young students of all ages interested. The “Rainbow Peepholes” are small radial diffraction gratings mounted in a cardboard disk, as shown in a Take Home Theme Packet in Figure 25 and in use by a young student in Figure 26. To demonstrate the effects of ‘imaging’ through a Rainbow Peephole, the photograph shown in Figure 27 was taken through a Rainbow Peephole while several students turned on their small pen lights.



Figures 25. Rainbow Peephole Take Home Theme Packet.
Figure 26. Student using the Rainbow Peephole and light.

Figure 27. Photograph taken through a Rainbow Peephole.

While fascinating for very young students, when gratings are assembled into low or medium cost spectroscopes, older students can use them to determine the spectral signatures of various gaseous elements as shown in Figure 28. Sometimes the lower cost spectroscopes, shown in Figure 29, do not provide as good a spectral images as the more expensive models with stands shown in Figure 28.

Figure 28. A group of gifted middle school students at a UCI summer astronomy program measuring optical spectra of various emission gases.

Figure 29. Lower cost plastic student spectroscope.

9.   THE OPTRICKS SUITCASE

Many of the components described in this paper can be found in the Optricks Suitcase now provided by the Optical Society of Southern California and the Optics Institute of Southern California. Most of the initial work in developing these outreach tools was completed by members of the Optical Society of America's Rochester Section who worked closely with their Southern California colleagues to expand the use of these outreach tools. To date, over ten thousand students around the world have been reached with these theme packets and it is the goal of this paper to get more optics professionals involved in the outreach efforts.

Figure 30 shows a photograph of the Optricks Suitcase with all its contents. Each suitcase comes complete with enough Take Home Theme Packets sets for 75 students. They also include a number of reusable components like the Fresnel lenses, Slinky, flashing lights, large glass lenses, large polarizer filters, large LCD film and a User's manual. The five Take Home Theme Packets include: Rainbow Peephole, Magic Stripes, Magic Dots, Magic Patch, and the Periodic Table with the Flyer on the back.

Figure 30, The Optricks Suitcase.

10. CONCLUSIONS

Providing excellent low cost optical components and systems for educational outreach programs enables students to experience impressive images that encourages them to further explore science through optics. From simple lenses, telescopes, and microscopes to polarizers, diffraction gratings and spectroscopes, all these common and simple components and systems can be used in novel and very effective ways to reach out to students and the local communities to help them be interested in and understand science. It is not even necessary for individual optics professionals to re-invent these tools, which has taken significant time, effort and funds, but they can obtain and use them to reach out in their own local communities.

In closing, you are left with two final figures, one of a young student who after being involved in a week long program at the UCI GSLA Exploratorium and experiencing the Optricks Suitcase presentation, was presented with a pair of "holographic" earrings which she is proudly displaying. Each female student was provided a similar pair and each male student was provided a similar pin. All of these were donated materials.

The last figure is "An Optical Joke" for your entertainment. The test tube filled with a mysterious liquid is held opto-mechanically at a short distance above the words "TITANIUM DIOXIDE" with 'titanium' being in blue ink and 'dioxide' in red. This interesting novel optical component, affectionately named, 'The Alpha-Numeric Optical Inverter' seems to invert the blue letters but not the red. The page under the optics has a few other sample words / phrases and not shown are some numerical examples.

For more information about these and other optical components and systems, please contact the author.

Figure 31. Young student showing 'holographic' earrings at the end of an Optricks Suitcase Presentation at UC Irvine GSLA Exploratorium.

Figure 32. An 'Alpha-Numeric Optical Inverter' inverts the blue letters and numbers but not the red.

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http://www.opticsexcellence.org/SJ_TeamSite/EducationOutreach.html

http://oisc.net http://www.ossc.org