Lessons learned from student outreach: introducing optics to fifth graders

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ABSTRACT

Though light and vision has been included in the Connecticut science standards for several years, teachers continue to look for new ways of teaching these concepts effectively. The students from the Three Rivers Community College SPIE and OSA student chapters have partnered with EASTCONN, a regional education service center, to bring optics lessons to the classroom. In this paper, the lessons that were demonstrated including spectroscopy, refraction, and reflection will be explained. With anecdotes from the student chapter members, fifth grade students and their teachers, the effectiveness of these lessons and steps to improve them will be presented.

Keywords: Connecticut Science Standards, student outreach, spectroscopy, reflection, refraction, laser engraving, kaleidoscopes, OSA and SPIE student chapters

1. INTRODUCTION

As an outgrowth of Jr. Laser Camp which brings fifth grade students in northeastern Connecticut to Three Rivers Community College (TRCC) for a day of optics explorations, the Three Rivers SPIE and OSA student chapters have partnered with EASTCONN to bring optics lessons into the fifth grade classroom. For the college student, presenting lessons to young students in their own lab at Three Rivers Community College is a comfortable situation with supplies readily at hand. However, going into the public school setting presents a new set of challenges.

These challenges can range from signing-in with the secretary at the school office to coordinating lesson times with the presenting students' own class schedule and the fifth grade teacher and bringing all the supplies required for the lessons. In addition, the facilitators must be able to adapt the lessons on site for less than ideal lighting situations, class periods which may range from 35 minutes to 60 minutes, working on small, wobbly desks instead of tables and be engaging enough to keep a group of fifth graders interested.

For this first year of outreach in the class room, teachers were asked which concepts they needed the most assistance in teaching. From that feedback, lessons in spectroscopy, refraction, and reflection with engaging hands-on inquiry activities to demonstrate these concepts were selected. The 5th grade students made spectroscopes, used lasers with gelatin optics for a refraction lesson, made kaleidoscopes and played "hit the target" a laser reflection game to learn about reflection and designed key tags and watched a laser engraver. The short descriptions of these lessons with examples of fifth grade student work are included in this paper. The work was funded mainly through outreach grants from SPIE and the OSA Foundation (OSAF).

2. DESIGNING THE YEAR-LONG CURRICULUM

Coordinating the outreach team schedules with the school schedules of two separate 5th grade schools required that this be a year-long program with sessions in November 2011, February 2012 and concluding with the culminating event at TRCC, Jr. Laser Camp in April 2012.

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Optics Education and Outreach II, edited by G. Groot Gregory, Proc. of SPIE Vol. 8481
84810I · © 2012 SPIE · CCC code: 0277-786/12/$18 · doi: 10.1117/12.929258

In selecting the lessons, it was important to the classroom teachers that their current curriculum was enhanced and lessons were aligned with the Connecticut Science Standards. At this point, light and vision appears only in the curriculum for 5th grade, which is why this grade level was selected for the outreach lessons. In table one, the Connecticut content standard is shown in the left hand column and the grade level expectation, the knowledge the student should achieve, is in the right hand column. Note that only the standards that pertain to this paper are included.

Using this information, the outreach team was able to select the lessons demonstrating the light spectra, reflection and refraction which most closely align with the standards.

Table 1. Connecticut Science Standards for 5th grade and GLEs[1]

Connecticut Content Standard Grade 5	**Grade level expectations** *Students should be able to:*
5.1 Sound and light are forms of energy.	1. Provide evidence that light travels in straight lines away from a source in all directions. 2. Investigate how light is refracted as it passes through a lens or through one transparent material to another. 3. Demonstrate that white light is composed of many colors. 4. Explain that all visible objects are reflecting some light to the human eye. 5. Contrast the way light is reflected by smooth, shiny objects (e.g., mirror or pool of water) and how it is reflected by other objects. 6. Measure angles to predict the path of light reflected by a mirror. 7. Determine whether a materials is opaque, transparent or translucent based on how light passes through it. 8. Design and conduct light absorption experiments that vary the size, length, direction and clarity of a shadow by changing the position of the light-blocking object or the light source.
5.2 Perceiving and responding to information about the environment is critical to the survival of humans.	1. Draw diagrams showing the straight path of light rays from a source to a reflecting object to the eye, allowing objects to be seen. 2. Describe the properties of different materials and structures in the human eye that enable humans to perceive color.

5.4 Humans have the capacity to build and use tools to advance the quality of their lives.	1. Generalize that optical tools, such as binoculars, telescopes, eyeglasses or periscopes change the path of light by reflecting it or refracting it. 2. Construct simple periscopes and telescope, and analyze how the placement of their lenses and mirrors affects the quality of the image formed. 4. Design and conduct simple investigations to determine how the shape of a lens or mirror (concave, convex, flat) affects the direction in which light rays travel.

3. SPECTROSCOPY

3.1 Lesson content: exploring light spectra

In presenting this opening lesson, Exploring Light Spectra, to the 5th grade students, the TRCC outreach team reviewed basic concepts of the light spectra including that light is a wave and that each color of light has a different wavelength, colors of the visible spectrum, and ROY G. BIV. They explained spectroscopy and how diffraction gratings work, though this was above the understanding of the 10 year olds. This is a "make and take" lesson so the participants make and keep a simple spectroscope (figure 1) consisting of a cardboard mailing tube, a laser-cut slit (made by the TRCC students) and diffraction grating. Safety is an important part of all lessons with young students and they were cautioned to "not look into the sun" with their spectroscope. It is also important that the supplies are easy to obtain and are inexpensive.

3.2 Presenting the lesson to the students

This first lesson, spectroscopy, was presented in the classroom of Mrs. Diane Wimmer at Brooklyn Middle School, Brooklyn, CT. Mrs. Wimmer has been participating in the Jr Laser Camp program for several years and because of this, it was determined the first outreach lesson would be presented in her classroom. The Three Rivers students were excited and arrived at the school with boxes of supplies and ready to sign in with the school secretary. They proceeded to the classroom and found it was not their lab at TRCC. The students' desks were a number of different heights and pushed together to form tables and had to be cleared of "stuff" before they could begin. The curtains on the windows did not really darken the room.

Because the class period was 50 minutes, the outreach team worked quickly to demonstrate the lesson and pass out supplies. The 5th grade students were excited and cooperative in following the directions. In making the spectroscopes, they were not always perfect…after all there were 21 excited students. Not all of the diffraction gratings were aligned properly with the slits but the young students did not care…they were wowed by seeing the light sources burst into rainbows through their spectroscope.

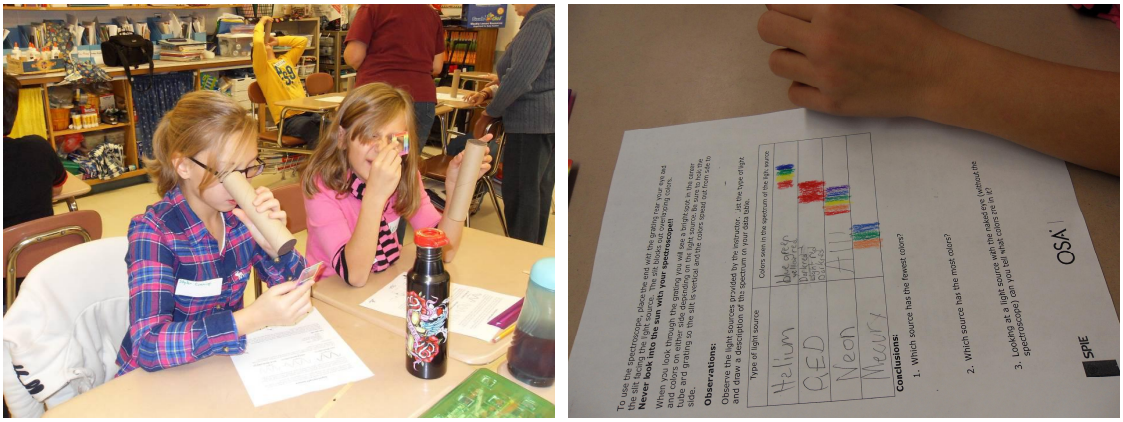

Figure 1. On the left, students making their spectroscopes and on the right, completing their worksheets of findings of light source spectrums.

After the construction, the outreach team continued the lesson by having the students analyze several different light sources . . . mostly multi chromatic but with one high brightness LED that is supposed to be mono chromatic (it was not). We then had them compare their findings (figure 1) with "official" (what we determined the spectrum was) findings. Most of them were spot on with their results. Finally, the students wrote their names on their spectroscopes and they took them home.

3.3 Debrief and impact of the lesson

After this lesson Tiffany, one of the outreach team members, observed, "Usually, the children are just happy to get out of the normal classroom activities, but once we started talking about spectrums, light having "different colors", and the safety surrounding lasers, the day turned into something more than I'm happy to get out of class. The 5th grade students were engaged in a higher level of science lesson and enjoyed instructors who were not their normal teacher." Because this was the first outreach lesson, we desired feedback from the participants. They completed a survey with a summary of the questions and responses shown in table 2 and much to the surprise of the outreach team, wrote personal thank you letters.

Table 2. Students' responses to post-survey light spectra lesson

Survey question 1: *what is the one most important safety lesson that was discussed when using a spectroscope?*
Student responses: • Never look directly at the sun • Do not look at the sun or laser. • Do not look directly at the sun of a light source.
Survey question 2: *If you used your spectroscope at home, what light sources did you look at?*
Student responses: • My lamp, the T.V., the sky • Light bulbs, mirror • Night light, glow sticks, candle

• Our fire pit while it was lit
Survey question3: *what was most interesting to you about this lesson?*
Students responses: • That you see a rainbow. • Making the spectroscope • The lesson. I thought it was cool. • Looking at all the different colors that came from light.

According to Mrs. Wimmer, the lesson would not have been as successful if the students were not already familiar with the material. In one of the thank you notes, Samuel wrote, "Thank you for bringing in all the cool lights and having us make the spectroscopes. I thought it was cool that it separated all the light so we could see all the colors of the rainbow." In conclusion, we learned we need to slow down the presentation of the lesson, but always emphasize safety.

4. REFRACTION

4.1 Lesson content: gelatin optics

Students in 5th grade in Connecticut are required to understand that light changes direction when it travels from one medium to another and how the shape of a lens affects the direction a light ray travels. Though they may not understand the math, they are wowed by a lesson in gelatin optics which uses laser pointers and gelatin to demonstrate refraction and the properties of lenses. As the team discussed the agenda for the day, they realized conserving gelatin would be one of their tasks. At the beginning of the lesson we decided to use an "optics magic trick" to engage the students in the concept of refraction. For this, we included the "disappearing beaker." Again, the cost for this lesson is minimal with gelatin and common vegetable oil being the consumable supplies.

For this second outreach lesson, the setting moved to the EASTCONN Conference Center, Hampton, CT. Within the science room, the students had access to a sink which helped with clean-up, white board to explain the lesson (refer to figure 2) and tables for the students. This also provided an opportunity to add a second class of students to the program. In addition to Mrs. Wimmer's class, Mrs. Dwire's class of 5th graders from Vernon, CT also attended.

4.2 Disappearing beaker

Taking the feedback from students and teachers from the first outreach session, the outreach team outlined an agenda for the day. This time, two sessions would be presented (one for each class of 20 students) and each session would open with an optics magic trick to engage the students. Matt Donnelly was the "magician" and presented the disappearing beaker: a small Pyrex® beaker placed into a larger beaker which is then filled with vegetable oil (refer to figure 2). The inner beaker "vanishes" because of index matching. The science of the demonstration and laser safety rules was also explained. This demonstration introduced the students to refraction.

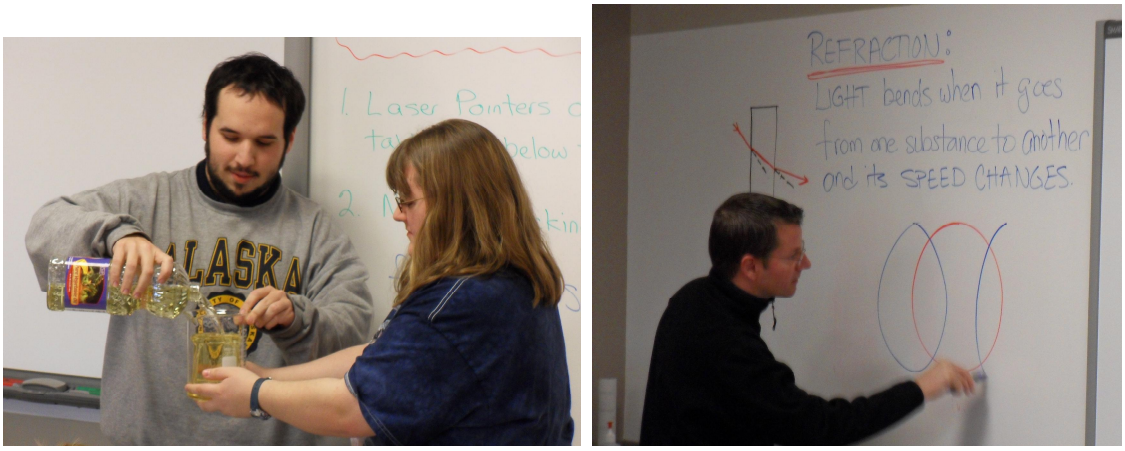

Figure 2. On the left, Matt and Tiffany preparing the magic beaker and on the right, Greg is demonstrating the lesson on how to cut the gelatin to make lens shapes.

4.3 Presenting the gelatin optics lesson to the students

Students worked in groups of 2 or 3 and each was give a small block of yellow firm gelatin, approximately 10 cm x 12 cm x 1.5 cm thick. The first task for the students was to use the laser beam from a laser pointer to intersect the gelatin block at different angles (refer to figure 3). The students drew the path of the beam where it entered the gelatin block and then where the beam exited the block demonstrating that the path changed. As the students indicated that they had an understanding of this concept they were given lens shapes cut with round cookie cutters. These included convex and concave lenses. Again, the students drew the paths of the laser beam as it entered and exited the lenses showing their understanding of how a lens works.

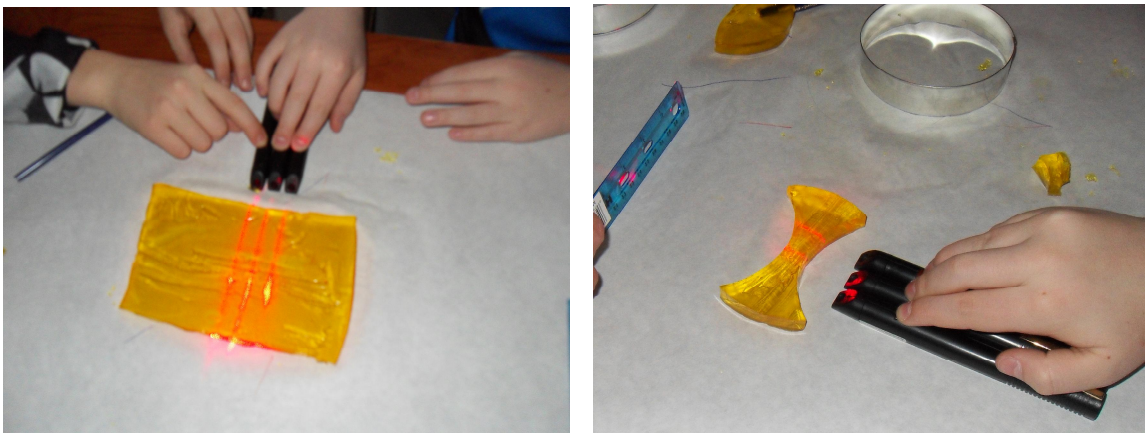

Figure 3. Gelatin optics lesson demonstrating refraction and lenses.

4.4 Debrief and impact of the lesson

Supplies for this lesson were messy and required the extra step of making the gelatin the night before so it would be firm for the lesson and transporting the gelatin. The advantage of presenting this lesson twice was that it gave the team an opportunity at the break between sessions to revise how to distribute the jello for the lesson and also the presentation of the lesson. The second presentation was more comfortable. One of the challenges with this lesson is no matter how

often the gelatin is handled by sticky fingers, the students want to eat it but for this we deferred to the classroom teachers and they said absolutely not.

We learned that it takes a lot of gelatin for 40 students. For this day, we also had many parent chaperones which helped with the clean-up. Mrs. Dwire said "this was the best field trip ever!"

5. REFLECTION

5.1 Reflection lesson content

Reflection is taught by the classroom teachers but our goal was to enhance the understanding, ensure that the students understood the "law of reflection", and provide some applications for mirrors such as beam steering devices as well as the more familiar imaging function to the students. The optimum setting for these lessons is at Three Rivers Community College in the outreach students' optics lab. This day is called "Jr. Laser Camp" and the students travel by bus to Three Rivers Community College.

5.2 History of Jr. Laser Camp

Jr. Laser camp is the last day with the 5th grade students and is at Three Rivers Community College. This gives the outreach students an opportunity to show off their labs and use tools that the 5th graders would not have access to such as the laser engraver and the workstations in the optics lab where they played the laser reflection game "hit the target." Students and teachers are treated to lunch and "make and take" projects including laser engraved name tags, Jr. Laser Camp t-shirts, and kaleidoscopes, which are generously funded through grants from SPIE, OSAF, and the Regional Center for Next Generation Manufacturing (RCNGM). For the 2012 edition of Jr. Laser Camp, reflection was the lesson theme.

The day started with bringing the students to a lecture hall and SPIE and OSA student chapter advisor Judy Donnelly assuming her role of college professor and presenting the lesson on the law of reflection. This set the stage to remind the students that even though they would be participating in very exciting workshops and making hands-on projects to take home, it was also a school day and school behavior was expected of all students.

We then explained the agenda for the day and that the students would be attending three workshops: kaleidoscopes; hit the target (laser target shoot); and laser engraving.

5.3 Reflection lesson: kaleidoscopes

This lesson was borrowed with permission from an OSA and SPIE outreach activity and we adapted it for our use. We were limited by time and so we shortened the lesson that was originally presented by OSA and SPIE. As an application of reflection, the students would first review how a set of two hinged mirrors reflect an object. They demonstrated how as the angle of the mirrors changes, the number of reflections does too. When they were presented with three mirrors, they discovered the number of reflections were too many to count.

For this "make and take" lesson, there were many supplies but the outreach students had become well practiced at handing out supplies and ensuring students follow directions. This lesson involved assembling mirrors, writing names on the tubes, and the most important part…selecting jewels and placing them in Petri dishes to attach to the tube ends to complete the kaleidoscope experience (refer to figure 4). Due to generous funding for this project, we did not have to conserve on how many jewels each students was given. The students were satisfied with the results.

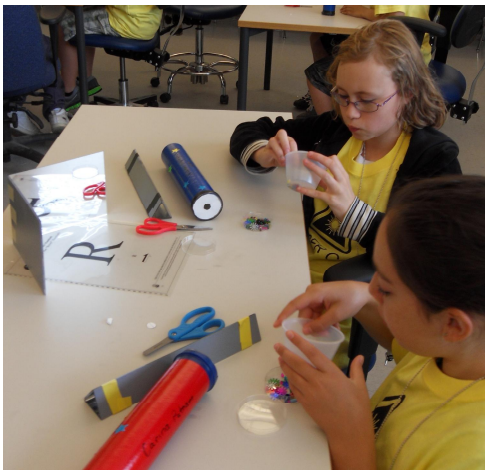

Figure 4.On the left, students are assembling their kaleidoscopes and on the right, a student is looking through the "giant bedazzle kaleidoscope."

5.4 Reflection lesson: hit the target (also called a laser target shoot)

Hit the target or also called the laser target shoot requires the students to work as teams 3 or 4 students to place mirrors so that when the laser is turned on, it hits a target. The students are given rulers, string and protractors to help them (figure 5) in lining up the laser to hit the target and score points. The target has different values and the results are totaled. This is a demonstration of how well the students listened to Mrs. Donnelly's lesson and to the outreach students' explanation of the rules of the "game." Fifth graders seemed to enjoy the laser target shoot because it was challenging to use a protractor and mirrors to predict where the light will end.

Figure 5 - On the left, students are measuring so they can "Hit the Target" and on the right, students are fascinated by watching the laser engraver.

5.5 Lesson: laser engraving

For the 5th graders, this is a "wow" workshop. Though they may not understand how the laser works, they learn that it is capable of making cool stuff. When asked what and where lasers are used, the fifth graders possessed a great deal of knowledge of laser applications. Some of their responses included laser pointers, cutting metal, surgery and telecommunication. It was surprising to the outreach team that they knew the lesser known applications like surgery and telecommunications. For this workshop, the students chose one of four line drawing images to be engraved by the 45 watt CO_2 laser (refer to figure 5). Students painted the resulting key tag to take home. While the engraver was working,

students were also treated to a demonstration of a 3D printer set up to make small hollow ducks. Several items created by the printer were also on display.

5.6 Debrief and impact of Jr. Laser Camp

At the end of this day, the outreach team was exhausted but there was clean-up to finish and classes to attend. The 5th graders were happy to go home with t-shirts and "make and takes." They enjoy wearing their t-shirts to school. A sample of student comments are included in table 3.

Table 3. Student comments on Jr. Laser Camp

Jr. Laser Camp: student comments:

- I had so much fun at Laser Camp.
- Watching the laser carve the wood was my favorite part. The laser was so precise.
- Thank you so much for our field trip. I had a blast.
- I really liked the kaleidoscopes because I really never knew how it worked or that there was three mirrors
- The target shoot was fun but challenging. I enjoyed my experience with the group.

6. CONCLUSION

This has been a very successful year of outreach. Though the number of 5th grade students participating in outreach lessons (42) is approximately the same as previous years, the number of lessons presented has increased from three to five with students taking home more projects (kaleidoscopes, spectroscopes, laser engraved key tags). We have found that between 40 and 50 students is the best number (refer to figure 6). Any more than that, and there are safety concerns and lab space limitations.

The teachers were very satisfied and appreciate that the lessons enhance their curriculum and are aligned with the Connecticut science standards. They would like to participate next year and always ask if more classes at their schools can participate. In addition, the reputation of the program continues to spread and teachers from Coventry, CT have asked to participate. The outreach group was also requested, and agreed to present 3 workshops, at an all-school science day at an elementary school in Mystic, CT.

From the outreach team perspective, in almost every case the lessons seemed appropriate. Most of the children were entertained and seemed to enjoy learning about the specific physical nature of light and how it would react in a given lesson. The lessons were good for the children in that the lessons taught about team building, sharing of information and good communication. The children seemed to enjoy thinking about the problems they were asked to solve and they liked seeing the outcome of their critical thinking. They were also appreciative of the outreach teams' efforts. Melina wrote in her thank you letter, "Thank you for our field trip! Thank you for dedicating your time to plan this fun field trip!"

A solid foundation of lessons has been established as the outreach students have learned to adapt the presentations to the attention span of the students. Challenge is one word that can describe what the outreach program does: challenging students to think, learn, and work together at an early age. Using the surveys, it has been shown that the lessons have an impact on 5th graders. They are eager to learn what is being taught, whether it is a giant kaleidoscope or a mirror challenge to hit the target using reflection. Many of the young students may just think of these exercises as fun games, but they don't realize the knowledge they have gained. Socially, they learn to work with those whom they do not like or get along with, learning that in situations you need to do the task at hand.

Figure 6 Students attending Jr. Laser Camp at Three Rivers Community College

ACKNOWLEDGEMENTS

Judy Donnelly, professor of Optics and Fiber Optic Technology at Three Rivers Community College (TRCC), Norwich, CT

Christina Dwire, 5th grade classroom teacher and students, Skinner Road School, Vernon, CT

Diane Wimmer, 5th grade science teacher and students, Brooklyn Middle School, Brooklyn, CT

Optical Society of America Foundation (OSAF) for funding and the kaleidoscope lesson

Regional Center for Next Generation Manufacturing (RCNGM), supported by the Advanced Technological Education Program of the National Science Foundation NSF/DUE #0903209 for additional funding of student workshops

SPIE outreach grant for funding supplies for the workshops

Spectroscope and hit the target activities were adapted from the PHOTON Projects of the New England Board of Higher Education, supported by the Advanced Technological Education Program of the National Science Foundation: PHOTON NSF/DUE #0053284 and PHOTON2 NSF/DUE ##0302528

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