Light: Connecting to Connecticut Science Standards

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ABSTRACT

With the inclusion of light in the Connecticut Science Standards for 5th grade, classroom teachers were faced with teaching an unfamiliar content area. At EASTCONN, a regional education service center, we were asked to provide teachers with professional development workshops which include essential background knowledge; assist with selecting curriculum aligned with the standards and which fit into an already packed teaching schedule; formative assessments; and finally, ensure that the curriculum provided students with inquiry-based, engaging hands-on lessons. In this paper, we will explore addressing these challenges and demonstrate engaging lessons aligned with the standards.

Keywords: curriculum, moon journals, Galileoscopes, science standards, formative assessment, reflection, refraction, kaleidoscope

1. INTRODUCTION

With the inclusion of light in the Connecticut Science Standards for 5th grade, teachers were faced with teaching an unfamiliar content area. This created anxiety for classroom teachers as they were asked to teach a content area for which they had little or no curriculum, materials or knowledge themselves. In addition, their students would be assessed on their science content knowledge of light and vision through the Connecticut Mastery Test (CMT). In this paper, we will explore addressing these challenges and demonstrate how existing curriculum can become engaging, hands-on inquiry based science lessons aligned with the standards.

At EASTCONN, a regional education service center which supports teachers and students in 36 school districts in northeastern Connecticut, we were asked to provide teachers with professional development workshops which would give the teachers the essential content knowledge they desired and assist in selecting curriculum that they could include in their already packed teaching schedules. For many teachers, this means squeezing a 60-minute lesson, three times a week into a classroom not designed for science. This is a challenge that we have met by presenting a series of workshops for teachers which provides them with essential content and the opportunity to practice the lessons they will be teaching to the students.

Teachers also like to include existing favorite lessons in their curriculum. One lesson is the common “moon journal.” We will demonstrate how the moon journal and other lessons can be developed into engaging inquiry based lessons using “make and take” projects that can be used as a model for any curriculum.

2. CONNECTICUT SCIENCE STANDARDS AND CURRICULUM

2.1 Connecticut Science Standards for grade 5 students

At first glance, the *Connecticut Pre-kindergarten–Grade 8 Science Curriculum Standards including Grade Level Expectations* published in March 2009[1] which includes the science standards for grade 5 students in Connecticut can appear daunting. It includes four content strands for each grade level from kindergarten through 8th grade. For 5th grade, the focus is sound, light and the senses. The table below shows the “*Grade Level Expectations*” (GLEs) associated with the Grade 5 science standards. The GLEs provide teachers with a more comprehensive explanation of the science concepts students should learn in each of the four content standard strands at each grade level. From this information, the typical science curriculum for a school is developed. For the purpose of this paper, only the GLEs which apply to our content area have been included in the table.

Optics Education and Outreach, edited by G. Groot Gregory, Proc. of SPIE Vol. 7783,
778307 · © 2010 SPIE · CCC code: 0277-786X/10/$18 · doi: 10.1117/12.860540

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.	6. Draw diagrams showing the straight path of light rays from a source to a reflecting object to the eye, allowing objects to be seen. 7. Describe the properties of different materials and structures in the human eye that enable humans to perceive color.
5.3 Most objects in the solar system are in a regular and predictable motion.	2. Construct models demonstrating Earth's rotation on its axis, the moon's revolution around the Earth, and the Earth and moon revolving around the sun. 3. Distinguish between the sun as a source of light and the moon as a reflection of that light. 4. Observe and record the moon's appearance over time and analyze findings to describe the cyclical changes in its appearance from Earth (moon phases).
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.

2.2 Teacher professional development workshops

The first step in preparing a well-rounded, engaging curriculum is to have teachers who are confident in their knowledge. With this in mind, we at EASTCONN have provided professional development workshops for teachers with a variety of teaching styles and needs. Workshops always begin with essential content knowledge. This includes a thorough explanation of the standards and demonstrations of the principles of light and concludes with the opportunity for teachers to practice the lessons before using them in their classroom.

After establishing a base of knowledge, workshop content will vary. Some teachers enjoy assembling their own materials and lessons. For these teachers, the PHOTON Explorations[2] are a wonderful resource. Teachers usually have some previous content knowledge and a basic supply of materials at their schools. These teachers select favorite lessons from the collection of PHOTON Explorations and enhance them for their classroom use. For these lessons, teachers also create their own assessments. For schools with few resources and for the teacher who is new to the curriculum, we have also offered "kit" based workshops. These have included Hands-on Optics (HOO) kits developed by the National Optical Astronomy Observatory (NOAO)[3] and the Science and Technology for Children (STC) *Light*[4] series published by Carolina Curriculum. The HOO kits provide materials and a teacher's guide; however, teachers must develop their own assessments. For the teacher with little preparation and planning time, the STC *Light* curriculum offers it all…materials, a comprehensive teacher's guide, assessments and student readers. Though a well designed kit, it is overly comprehensive and costly for most of our districts in northeastern Connecticut. This curriculum is designed as a six week learning module for a typical middle school in which science is taught every day.

Another factor to consider in planning the year long curriculum is that many teachers "fit" science in between language arts, math and everything else, including "specials" such as art, physical education and music. As can be seen, there is no single curriculum that fits every classroom. Most teachers, being a resourceful group, take a variety of materials and create their own curriculum which fits their needs. In this paper, we will take existing curriculum and enhance it to become more engaging and meaningful to the typical 10 to 11 year old, 5th grade student, and present it in a way that allows it to still fit into the limited class period in which science is taught.

3. APPLYING CURRICULUM TO THE STANDARDS

Some teachers have existing curriculum that they would like to enhance and "fit" the standards. From the Connecticut standards, we will take the content areas of refraction, moon phases and reflection and we will show how this can be addressed through a variety of inquiry based, engaging hands-on lessons. We will also demonstrate how moon journals, a common form of curriculum, can become more interesting for the students by using a telescope. For each of the example lessons, the students learn about the optics principle first and then apply that principle to a take home activity.

3.1 Make and take lessons

One way to create a lesson that is highly engaging is to use a take home activity also called a "make and take." With a "make and take" project, students build a hands-on learning project which is theirs to keep. The "make and take" illustrates the principle we are teaching using hands-on learning and then the students use the project at home. By sharing and demonstrating what they have learned with their family, students involve siblings and parents in the learning process. These items must be cost effective and made from easily obtainable items. In the past, we have made spectroscopes, but for these lessons we will use Galileoscopes, moon journals and kaleidoscopes.

3.2 Refraction and Galileoscopes

For our lesson on refraction, we chose the Galileoscope[5] as the accompanying make and take. The Galileoscope is a refracting telescope available as a kit and developed by astronomers and educators to celebrate the The International Year of Astronomy 2009. In the past, we have made the cardboard tube telescopes but found the Galileoscope to be an improvement in quality and offered more opportunities for learning. For a cross-curriculum literacy lesson, we used the book, *Galileo's Journal 1609-1610*[6] by Jeanne K. Pettenati. With its outstanding illustrations, this book not only tells the story of Galileo inventing the telescope but also is an example of a science notebook, a format the students use for their moon journals.

To celebrate the 400th anniversary of Galileo inventing the telescope, we hosted a workshop (see Figure 1) for over 100 students in Connecticut and via an on-line program, their pen pal partners in Aurora, Colorado; Miramichi, New Brunswick, Canada; and Slatina, Romania. Through funding from the Optical Society of America Foundation (OSAF), our students were able to build and take home over (200) Galileoscopes. A student from Brooklyn, CT wrote about the experience, "When we built the telescopes was fun but being able to use them was even better."

Figure 1. Connecticut students assembling their Galileoscopes at our workshop.

Before building the Galileoscopes, our students were introduced to refraction and lenses through an optics lesson provided by Judy Donnelly, professor of Lasers and Fiber Optic Technology at Three Rivers Community College (TRCC) and students from the SPIE student chapter at TRCC. Students used ray boxes (see Figure 2) to explore a variety of lenses and geometric shapes to understand refraction. By using this lesson, we were able to incorporate many of the GLEs, including (refer to Table 1) 5.1.2; 5.4.1; 5.4.2; and 5.4.4. By looking at each component of the lens assembly individually, the students developed a better understanding of how a refracting telescope works.

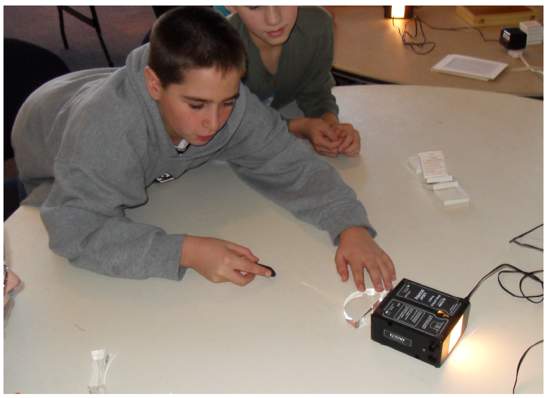

Figure 2. Students using ray boxes and geometric shapes to learn about refraction.

Figure 3. Connecticut student using her Galileoscope to make a field observation.

To complete the lesson, students demonstrated their understanding by completing field observations (see figure 3). The students were initially surprised that the objects they viewed were upside down, but were able to include that view in their sketches. Teachers and students were confident that they would be able to use the Galileoscopes to observe the moon and enhance their understanding of moon phases.

3.3 Moon phases and moon journals

Moon journals are a standard part of the curriculum for 5th grade. In the simplest format, students make an observation each night of the moon for a complete cycle of moon phases. It is also an introduction to science notebooks by teaching students how to write “like a scientist.” To write like a scientist, students include facts, wonderings, and all details about an observation but do not have to write in complete sentences, which is contrary to other journal writing styles. Doing this activity could become tiresome for students if it only includes noting the phase of the moon. For some students, the idea of going out night after night, in the cold, to look at the moon is not very appealing. One of the methods teachers use to make this lesson more interesting is to ask the students to include details about the weather, time, temperature, a sketch and a short written description or sometimes a poem (refer to figure 4 for an example from a student moon journal).

With our inclusion of the use of the Galileoscope and comparing journal entries with international pen pal partners, this becomes a more interesting and engaging lesson. With the Galileoscope, the students had a close view of the details of the moon to include in their journal entries. Students had varying degrees of success using their Galileoscopes. One student who had trouble using the Galileoscope asked her parents to borrow their binoculars. Those students who were successful were excited by the detail. In a blog entry from January 27, 2010 one of our partner students in Miramichi, New Brunswick, CA wrote (translated from French), “I watch the moon on my deck with my Galileoscope week past. The moon seen as a very very big banana!”[7]

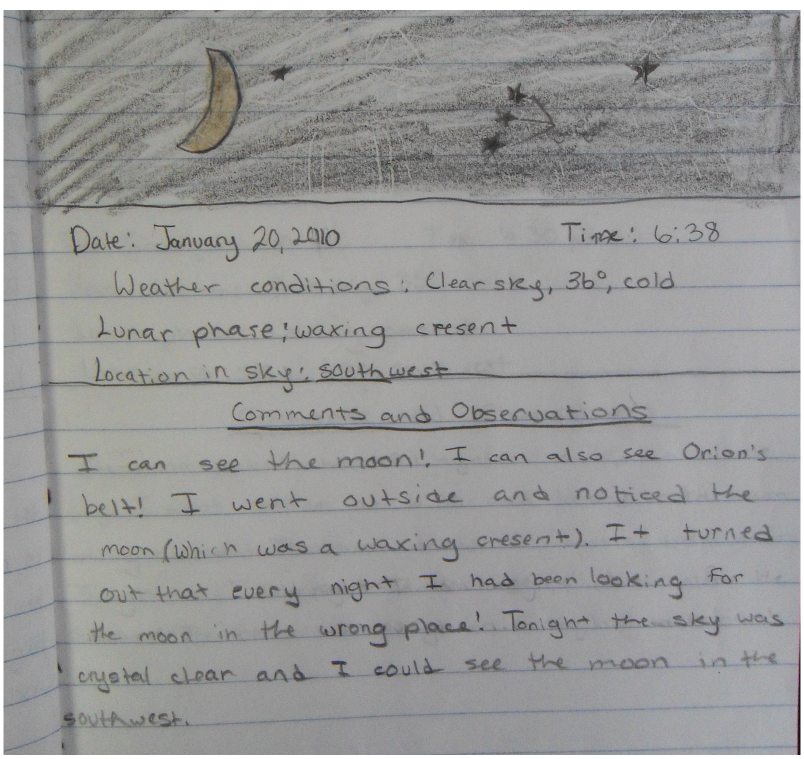

Figure 4. Excerpt from student moon journal.

Our partners in Miramichi, New Brunswick used an on-line blog for their moon journals. Their blog, “The Natural Sciences: Project Dark Skies” was developed in conjunction with our pen pal program. The goal of their blog was for “both groups to continue to share their ideas and will direct their attention to the observation of space and pollution of outdoor lights. Students have access to their own telescopes, which they call Galileoscope, and they can share their observations with this blog.”[7]

To further illustrate their understanding of the phases of the moon, most of our students also complete a visual project. The Connecticut GLEs that are addressed by this project are (refer to Table 1) 5.3.2; 5.3.3; 5.3.4; and 5.3.5.

3.4 Reflection and kaleidoscopes

As is shown in the pre-assessment formative assessment probe “Can it Reflect Light”[8], students think of reflection in a traditional manner that a surface must be mirror-like or “shiny” in order to reflect. It is important for students to understand how a mirror reflects light.

It is not until students practice the law of reflection and not just read about it, that they truly understand it. For this lesson on reflection, we invited the 5th grade students to a workshop in the optics lab at Three Rivers Community College. Students practiced “hit the target” (see Figure 5) using lasers, mirrors and protractors. Starting with a single mirror, the students were surprised how difficult it was to use the law of reflection to “hit the target”.

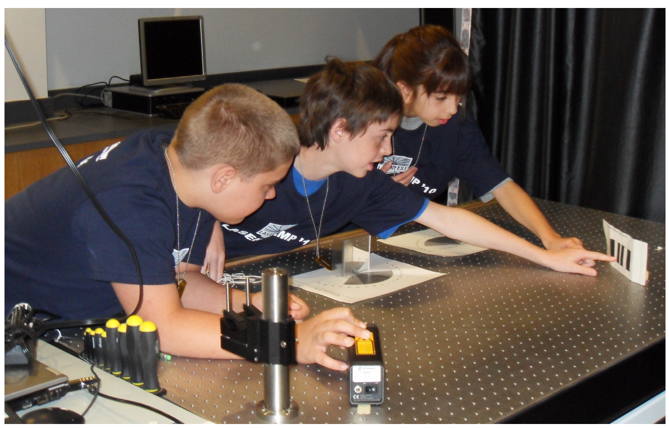

Figure 5. Students practicing “hit the target” at Three Rivers Community College.

To conclude the lesson on reflection, as a special guest of this meeting of 5th graders, Barbara Darnell, secretary of the New England Section of the Optical Society of America (NESOSA), demonstrated her giant telescope. Barbara showed the students how the kaleidoscope worked with its three mirrors. Students were thrilled to see their faces in the reflection (see figure 6). For the “make and take” project, the students assembled inexpensive kaleidoscopes to take home. Once again, this lesson was aligned with Connecticut standards and the GLEs, including (refer to Table 1) 5.1.6 and 5.4.2.

Figure 6. Student looking at her reflection in the “giant kaleidoscope.”

4. ASSESSMENT

4.1 Connecticut Mastery Tests (CMTs)

5th grade teachers have the added expectation of preparing their students for the science portion of the Connecticut Mastery Test (CMT). Though the CMTs also assess math, language arts and writing skills, the science portion is only given to students in 5th and 8th grade. Because the CMT tests are given in March of each year, the teachers, in order to fully prepare their students, attempt to cover the entire grade-level science curriculum by the end of February. In addition, the science content from 3rd and 4th grade is also included on the science portion of the CMT given in 5th grade, so a brief review of that content is also included.

The final piece driving the curriculum is whether the students are prepared for the CMT. The Core Science Curriculum Frameworks for Connecticut[1] include not only the standards for science which are to be taught but also describes what students need to know in order to be able to successfully complete the CMT. These are the *expected performances* and identify the specific knowledge and abilities from the broader curriculum that will be assessed on the statewide tests given at Grades 5, 8 and 10. The left hand column of the table, below, shows the specific standards for 5th grade which we will address. In the right hand column, is the corresponding CMT correlation or expected performance level for each standard listed on the left.

Table 2. Connecticut science curriculum frameworks and CMT correlation[1]

Connecticut Science Standards 5th grade Core Science Curriculum Framework	**CMT Correlation**
5.1.b. Light is a form of energy that travels in a straight line and can be reflected by a mirror, refracted by a lens, or absorbed by objects	**B19.** Describe how light is absorbed and/or reflected by different surfaces.
5.2. a The sense organs perceive stimuli from the environment and send signals to the brain through the nervous system.	**B20.** Describe how light absorption and reflection allow one to see the shapes and colors of objects.
5.3. a. The positions of the Earth and moon relative to	**B23.** Describe the monthly changes in the appearance of

the sun explain the cycles of day and night, and the monthly moon phases.	the moon, based on the moon's orbit around the earth.
5.4. a. Advances in technology allow individuals to acquire new information about the world.	**B25.** Describe the uses of different instruments, such as eyeglasses, magnifiers, periscopes and telescopes, to enhance our vision.

4.2 Formative assessment

Teachers use many methods of assessment to ensure students are thoroughly prepared for all aspects of the CMT. One method which requires students to use their inquiry and writing skills is the use of *formative assessments.* Formative assessments are used to gather information about student learning throughout the teaching and learning process and provide a gauge to inform teaching practice (e.g. do some students need more help to understand a concept?). Assessments are often more effective when they are <u>not</u> the end product of a lesson and can help with determining student misconceptions.

For example, we used the formative assessment probes "Can It Reflect Light?"[7] and "Going Through a Phase"[7] from the book *Uncovering Student Ideas in Science: 25 Formative Assessment Probes Vol.1-4*, by Keeley, Eberle, and Farrin, to gather information about students' understandings of reflection and moon phases.

4.3 Formative assessment probe "Can it Reflect Light?"

The purpose of "Can It Reflect Light" is to elicit students' ideas about light reflection off ordinary surfaces and materials. Referring to Table 2 above, this specifically applies to CMT correlation B20. In this assessment writing activity, a list of 24 items is provided to students (including items such as glass, gray rock, leaf, shiny metal, wood, etc.) and students are asked which ones reflect light. Students are also asked to describe the "rule" or reasoning they used to decide if something can reflect light. This assessment was given to students *after* completing their units of study on light.

Results of this assessment show that students still believe that a mirror or other shiny surface is the only item that reflects light demonstrating that they do not truly understand how the human eye sees objects. No student selected all 24 items and most selected between five and ten. Student responses included "I think the rule for reflecting light is that the surface has to be flat, smooth and sort of shiny to reflect light." Another student wrote, "because if it is dull it will absorb light instead of reflect." Because they also must explain their thinking, the teacher has an additional tool to understand student viewpoint and knowledge. At this point, the teacher can then revisit the lessons which will help the students to understand this topic.

Our teacher from Franklin Elementary School, CT, Joanne Gearity, who used the assessment in her classroom, provided this feedback, "At first, the class was concentrating on smooth, shiny surfaces for reflection. Then we had an "aha" moment and realized that everything we see is because of light reflected to our eyes. When we got the packet [explaining the assessment], we were pleased that our "discovery" was confirmed."

4.4 Formative assessment probe "Going Through a Phase"

Another example of a formative assessment is "Going Through a Phase." This assessment was used as a pre-assessment given to students before beginning their units of study on moon phases. This provides the teacher with the base knowledge of the students and with this information, the teacher can develop lessons which are closely aligned with student needs.

In Table 3, is the situation that is presented to students in "Going Through a Phase." The purpose of this assessment is to uncover student understanding of what causes the Moon's phases.

Students were asked who they agreed with and to explain their thinking. In surveying 88 students, what is most interesting is not the number who answered correctly but the 24 students who agreed with Raj (11), Drew (5) Mona (3), Oofra (2), none (2) and Drew (1).

Students justified their responses as follows: about Raj, "I agree with Raj because I heard that explanation before" and "Raj because the moon does get a little bigger every day and a little smaller after the full moon." Another student wrote, "I agree with Oofra because the sun's shadow does block part of the moon."

Table 3 "Going Through a Phase" formative assessment taken from *Uncovering Student Ideas in Science: 25 Formative Assessment Probes Vol. 4*, by Keeley, Eberle, and Farrin

Mrs. Timmons asked her class to share their ideas about what causes the different phases of the Moon. This is what her students said: Mona: The Moon lights up in different parts at different times of the month. Jared: The phases of the Moon change according to the season of the year. Sofia: Parts of the Moon reflect light depending on the position of the Earth in relationship to the Sun and Moon. Drew: The Earth casts a shadow that causes that causes a monthly pattern in how much of the Moon we can see from Earth. Trey: Different planets cast a shadow on the Moon as they revolve around the Sun. Oofra: The shadow of the Sun blocks part of the Moon each night causing a pattern of different Moon phases. Natasha: the clouds cover the parts of the Moon that we can't see. Raj: The Moon grows a little bit bigger each day until it is full and then it gets smaller again. It reappears this cycle each month.

This data also provides the teacher with the knowledge to provide differentiated instruction. Those students who have grasped the concept can go deeper into their study. More hands-on explanation can be provided to the students who need more help understanding the concept. This assessment was given to students before starting their moon journals and poster projects showing the position of the moon phases in relationship to the sun and earth.

5. CONCLUSION

By using three specific lessons (telescopes, moon journals, and kaleidoscopes) with their accompanying assessment opportunities, the Grade 5 Connecticut Science Standards have been addressed. Each of these basic lessons were provided to students in one hour time frames, though to be most effective they should be expanded to several class periods to allow the students to explore the principles of light more thoroughly. In addition, by taking home each of the items; students were able to involve their families in their science learning. The best gauge to the effectiveness of a program is comments from students. One of our students from Brooklyn, CT had this to say about building the Galileoscopes, "the December field trip was one of the best field trips I have ever had in my life. It was full of excitement. My favorite part of the trip was when my class built the telescopes. It was challenging trying to find all the pieces and having to be at a crowded table. It was fun too at the end when we got to look out the window with our new telescopes."

ACKNOWLEDGEMENTS

Barbara Darnell and the New England Section of the Optical Society of America (NESOSA), and it was under that aegis that the giant kaleidoscope was constructed and presented at 5th grade optics workshop.

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

Optical Society of America Foundation (OSAF) for funding the Galileoscopes and supplies for Jr. Laser Camp workshops.

Regional Center for Next Generation Manufacturing (RCNGM) for additional funding of student workshops.

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