

# Innovative Methods to Teach Optics in the Grade 5 Classroom

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**Abstract:** With the recent realignment of the Connecticut State Department of Education Core Science Curriculum Framework, light and vision were added to the science curriculum for 5<sup>th</sup> grade students and they will be tested on these concepts on the Connecticut Mastery Test (CMT) starting in 2008. In order to ready students for the test, our collaboration began with the development of a standards-based workshop to introduce optics concepts to fifth grade students in eastern Connecticut. After a successful initial workshop for students, it was apparent that more students would benefit from our lessons if their teachers were able to conduct the lessons in their own classrooms using authentic curriculum. We also found that the teachers were desperate for curriculum, knowledge and supplies to be able to teach the concepts. The result is a collection of lessons satisfying the needs of younger students and a professional development workshop for teachers in which hands-on lessons, scientific inquiry, and scientific literacy are combined to deepen the understanding and interest in the study of optics.

## Introduction

### *The Connecticut Core Science Curriculum Framework*

As shown in the excerpt (Table 1) from the *Connecticut Core Science Curriculum Framework Content Standards and Expected Performances – Core Science for grades 3-5* document, the state of Connecticut has included the study of light and vision for all 5<sup>th</sup> graders. It is important to note that this is the only appearance in the K-8 Science curriculum for the study of light and vision that is required by the state of Connecticut.

The Connecticut Core Science Curriculum Framework document is organized so that the *left* column is the *Content Standards*. These items are “narrative statements of science concepts that guide the development of a rich and rigorous curriculum.” [1] Each *Content Standard* includes:

- A conceptual theme, followed by an overarching guiding question
- The content standard, a broad conceptual statement identified with a numerical code that serves as a general learning goal for the unit of study
- One or two supportive concepts, identified with bullets, that provide more specific information about the focus of the learning unit. [2]

In the *right* column are the *Expected Performances*. This is “the specific knowledge and abilities from the broader curriculum that will be assessed on the statewide tests given at Grade 5, 8, and 10.” [3] The 2008 CMT is the first time that students in Grade 5 and 8 will be tested for their knowledge of science content.

In addition to *Content Standards* and *Expected Performances*, students are expected to understand and use scientific inquiry, literacy and numeracy in their study of the content subject. Scientific inquiry, literacy and numeracy are

considered an integral part of the content standards for each grade level. More specifically, these topics are defined in the *Content Standards* as follows:

- Scientific Inquiry – a thoughtful and coordinated attempt to search out, describe, explain and predict natural phenomena.
- Scientific Literacy – speaking, listening, presenting, interpreting, reading and writing about science.
- Scientific Numeracy – mathematics provides useful tools for the description, analysis and presentation of scientific data and ideas. [4]

Table 1. Excerpt from Connecticut Core Science Curriculum Framework Content Standards and Expected performances – Core Science for grades 3-5. [5]

Grade 5 Core Themes, Content Standards and Expected Performances	
Content Standards	Expected Performances
<p><i>Energy Transfer and Transformations – What is the role of energy in our world?</i></p> <p><b>5.1 – Sound and Light are forms of energy.</b></p> <ul style="list-style-type: none"> <li>◆ 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.</li> </ul>	<p><b>B 19.</b> Describe how light is absorbed and/or reflected by different surfaces.</p>
<p><i>Structure and Function – How are organisms structured to ensure efficiency and survival?</i></p> <p><b>5.2 – Perceiving and responding to information about the environment is critical to the survival of organisms.</b></p> <ul style="list-style-type: none"> <li>◆ The sense organs perceive stimuli from the environment and send signals to the brain through the nervous system.</li> </ul>	<p><b>B 20.</b> Describe how light absorption and reflection allow one to see the shapes and colors of objects.</p>

### Student Workshop – Introducing Optics

Because the study of light and vision is brand new curriculum, we wanted to introduce the concepts to as many students as possible. Our goal was to cover as many of the *Expected Performances* as possible in the short time available with maximum engagement and hands-on activities by the students. After careful evaluation, we selected lessons in which the students would study refraction, absorption, and the visible light spectrum. The lessons were presented in May 2006 at a student workshop entitled “A Little Light Magic” and included three content lessons with one of the lessons integrating scientific writing.

For the initial workshop, the students were participants in a program entitled “*Systems Explorers*,” an EASTCONN Interdistrict diversity program funded through the state of Connecticut. Serving the eastern Connecticut region, EASTCONN is one of six regional educational service centers (RESCs) providing educational services and training to students and teachers. The “*Systems Explorers*” program encourages teams of students from diverse backgrounds in grades 5-8 to build positive relationships, critical thinking and problem solving skills by working together in cross-district partnerships. This group of 350 students from rural and at-risk urban schools in eastern Connecticut provided us with an ample number of students to thoroughly evaluate the optics lessons we selected for content and scientific method.

All of our workshop lessons were adapted from the PHOTON Explorations, developed under the National Science Foundation (NSF/ATE) supported PHOTON and PHOTON2 projects. PHOTON and PHOTON2 were faculty professional development, laboratory improvement and curriculum development projects of the New England Board of Higher Education, funded by the Advanced Technology Education program of the National Science Foundation.

PHOTON used a traditional summer workshop model for teachers from the New England states, while PHOTON2 delivered a hands-on collaborative course to teachers across the United States by online distance learning.

We developed our lessons from favorite demonstrations of the participants in the PHOTON and PHOTON2 project, which have been edited and compiled into the PHOTON Explorations. The chosen Explorations best represented the concepts that the students are required to understand, while also providing highly engaging activities. They clearly demonstrated the procedures, activities, observations, and important findings and required the students to use scientific inquiry in their activities while also providing the necessary background information that the teachers needed to present follow-up lessons in their classroom. Though designed for the middle school and high school level, they were easy to adapt to the introductory 5<sup>th</sup> grade level.

The following PHOTON Explorations were selected:

- Exploring Light Spectra
- Exploring Refraction (Jell-O® Optics)
- The Magic Box

Using these engaging lessons, students created mailing tube spectroscopes for viewing a variety of light sources (the visible light spectrum), studied refraction, absorption, and transmission using Jell-O® Optics and practiced scientific writing in a lesson which used the “Magic Box” (a demonstration of polarization that creates the illusion of a solid wall in an otherwise empty box for a study in observation.)

### **Summary of Explorations:**

#### *Exploring Light Spectra*

In this Exploration, each student built a spectroscope using a short mailing tube, diffraction grating slide, and cardboard disk with a narrow laser-cut slit.

This lesson provided the basic ideas of light essential to the understandings of all of the *Expected Performances*. Students were introduced to the fundamental colors of light, the visible spectrum and wavelengths and were especially thrilled to learn about ROY G. BIV. They examined the colors radiated by several unique light sources including fluorescent bulbs, gas tubes, filtered incandescent sources, lasers and LEDs (refer to photo 1). As part of their written work, students were required to complete a data table identifying the unique spectrum of each light source (refer to photo 2). By doing this, they were able to compare the light sources and speculate how the light was produced.

Photo 1. *Exploring Light Spectra* Exploration – student using spectroscope.



The highlight of this lesson was that the students were able to take their spectroscopes home. This is an important part of this lesson as the students were thrilled to be able to share the spectroscopes with their families. They not only were able to tell their families about the workshops but demonstrate and explain what they had learned using light sources within their homes. Of course, each spectroscope bore a safety label, affixed by the students themselves so they would be sure to notice, warning against looking at the sun or into a laser source. The safety label made a strong impression on the students. "Tim" wrote, "The spectroscopes we took home I used numerous times. Don't worry, I haven't looked into the sun." Another student wrote, "Thank you for letting us make our own spectroscopes and take them home. I look at all kinds of lights to see what color the spectrum will be. I always make sure not to look into the sun."

Photo 2. *Exploring Light Spectra* Exploration – student completing data table.



In a follow-up writing activity, students were asked to describe their favorite activity. "Kelsey" wrote "It is very hard to pick a favorite activity of the three. All of them were very fun and informative. I think the Spectroscopes was my favorite though. What I liked about Spectroscopes was how we got to build our own scopes and try different lights to see what colors make them. Plus, we got to take them home so we could use them ourselves. It was interesting how what colors you see in a light may not be what color(s) made it. Then we used a graph to record our data and see which light was the purest. The purest light has the least colors of royg biv (red, orange, yellow, green, blue, indigo, and violet) in it when viewed through the Spectroscope. The purest light we viewed was the exit sign, which had only the color red. The least pure was the fluorescent light which had all of the royg biv colors. My very favorite part about the Spectroscope was that I learned a lot of things I didn't know before. At first, I didn't even know there was anything called royg biv or that colors unseen make the light you see. I didn't know there was such a thing as a Spectroscope either. I also liked how the Spectroscope activity let us take part of what we learned home. I use my spectroscope all over my house now. The light over my stove in my kitchen is more pure than the one over my dinner table."

Kelsey continues to describe the activity in more detail, "To build the Spectroscope was actually very simple. We used a cardboard tube and glued a circle of black construction paper with a slit in the middle to one side. We looked through the other side so that we could concentrate on one light at a time. Then, on the side we looked through, we looked through the grating and the tube to see lights and focus on only one of the lights. If we didn't have the tube and slit, we'd be seeing all different lights and confusing colors through the grating. On either side of the slit, you could see the royg biv colors that made the light you were viewing. The grating made this appear. It was very fun and interesting!"



*Exploring Refraction (Jell-O® Optics)*

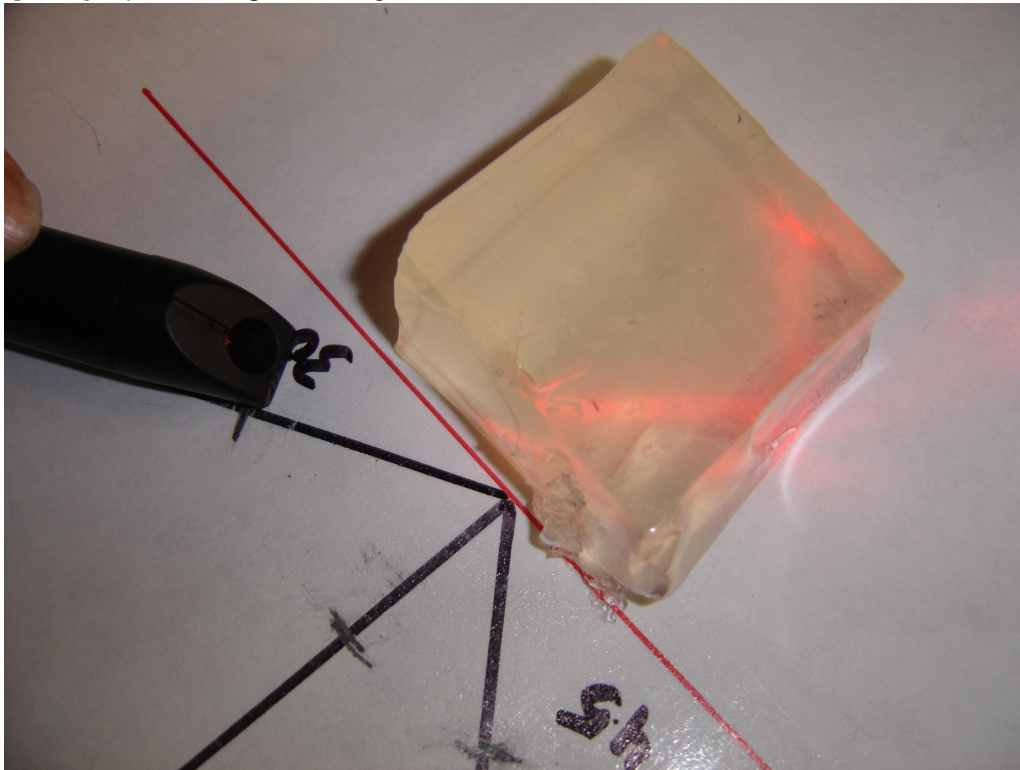
For this Exploration, students studied refraction, absorption, and how light travels through concave and convex lenses using laser pointers and plain gelatin blocks (Knox® brand) and various colors of Jell-O® Jigglers®.

This activity is also a demonstration of how an ordinary kitchen item can be used in a scientific lab. The blocks, concave and convex lenses were cut from trays of gelatin Jigglers® made using the recipe on the box of either the Knox® or Jell-O® brand gelatin. At this point, it was also the appropriate time to introduce and stress laser safety and safe practices in lab science. In order to participate in the activity, the students were introduced to the safety instructions. Refer to Table 2 for a list of the safety rules used for this workshop. Again, background knowledge was introduced on the behavior of light rays when transmitted through lenses and different media. Students used a block of gelatin (refer to photo 3) to demonstrate how a beam of light bends when it travels from air into a medium where it travels more slowly (gelatin). In further investigation, they used concave and convex lenses cut from gelatin to show how light behaves when traveling through a lens.

Table 2. Laser Safety Rules from “A Little Light Magic” student workshop.

Laser Safety Rules
1. Laser beams stay below the waist (laser pointers stay on the table.)
2. Never aim the laser beam directly into your eyes or the eyes of others.
3. Please respect the equipment so it can be used by others.
4. If you cannot follow the rules, you will be asked to sit out of this activity.

Photo 3. *Exploring Refraction* Exploration – gelatin block.



Students were highly engaged in this investigation because of the nature of the supplies (refer to photo 4). Vinny wrote “My favorite activity was using the lasers to see it refract in different directions off the jello.” Another student, Andrew described the activity this way, “I liked to see the light bounce right off of the jello. I also liked to learn that different shapes and angles made a difference to how the light came out.”

Photo 4. *Exploring Refraction* Exploration – student using laser pointer to demonstrate refraction.



#### *Exploring Polarization – The Magic Box and Science Journal Writing*

For this lesson in scientific writing, the Exploring Polarization – The Magic Box Exploration was used. A portion of the CMT will require the students to write in a “scientific” manner which differs from the expected style of writing on other portions of the test. Short responses with “just the facts” will be more appropriate for this portion of the test. For the lesson, the students first reviewed “descriptive” writing and were required to write about an everyday object in a descriptive manner. Then writing for science was introduced with an example of describing an object with “just the facts.” Table 3 demonstrates the descriptive and scientific writing examples that were shown to the students. For this portion of the activity, the students broke into small groups and one student would write a description of an object. The other members of the small group would attempt to draw a picture of the object using the written description. Students often find writing boring, however, Brian found this lesson very engaging. He wrote “My favorite activity was the writing project because you got to write directions and someone else would try the best they could to do what you wanted. The favorite stations at the writing project was the one that you would draw a simple picture and write how to draw the picture. Then you would compare your pictures and see if they followed the directions correctly.”

At this point the “Magic Box” was shown to the students and they were asked to describe what they saw (refer to photo 5). The students were not required to understand how polarization works as the box was the vehicle to inspire students to write scientifically. Many of the students were uncertain about what they were seeing. They were quite surprised when the instructor for this lesson passed a chopstick through the “solid wall.”

Table 3. Descriptive and scientific writing examples.

Descriptive Writing	Scientific Writing
The yellow wooden pencil lies quietly on the desk waiting for someone to pick it up.	The pencil is made of wood, painted yellow and measures 6 inches long. It is laid horizontally along the table edge.

Photo 5. *Exploring Polarization* Exploration – student using “The Magic Box”.



**Conclusions from the student workshop and establishing the need for teacher professional development:**

By using a workshop format, we were able to introduce optics to a large number of students in a very short amount of time. Each session lasted 50 minutes with about 60 students in each session. To staff the workshops, we each instructed one of the three sessions and used a literacy consultant to instruct the third session (the workshop in scientific writing). This enabled the classroom teachers to work with individual students who needed additional help. One of the most important results was the positive feedback from students and that they were very appreciative of the use of “real” supplies. Many students commented on how exciting it was to make a “real” spectroscope and use lasers. Several students wrote, “My favorite activity was the laser jigglers. I like it the most because you got to use a real laser.” Another important result was how quickly the students learned the new vocabulary and how they were able to understand the principles of refraction, spectroscopy and the visible spectrum and were also able to write about these concepts. Obviously, the students were engaged and interested in the topics.

However, our workshop was only an introduction and it was obvious that in order to serve the entire northeast region of Connecticut and for the students to truly understand the lessons, teachers also needed a workshop dedicated to the study of light. By teaching the lessons themselves, teachers could also reinforce the concepts from our introduction to optics, explore more topics and answer student questions with more details than our time allowed.

The needs of the teachers were somewhat different than the students. They required not only more in-depth background knowledge of what they were teaching but also sample lesson plans aligned with the standards and lists

of where to purchase low cost supplies and what to buy. Because most of the teachers attending the workshop were classroom teachers, they had little or no specific optics knowledge. The lessons needed to be presented in a clear, concise step-by-step manner with supplies that could be easily obtained and organized.

We developed a full-day professional development workshop, attended by 23 teachers, mostly from grade 5 but teachers from other grade levels were welcome to attend. In addition to the previous lessons, the teachers participated in other hands-on investigations introducing color perception and mirror reflection. Complete instructions and explanations for each activity, print and web resources for teaching optics, and a packet of additional learning resources for teacher and student were given to teachers. Again, PHOTON2 Explorations were adapted.

#### **Additional lessons for professional development workshop:**

##### *What Color is a ...? Reflection of Colors*

This Exploration introduces the concepts of how the eye recognizes colors, and the absorption, scattering and reflection of light. This investigation involves trying to fool the eyes with different colors of light sources. By viewing objects first illuminated by color LEDs and then in white light, participants were visually able to understand how the eyes see color. Teachers suggested additional classroom experiments based on the same principles: for example, asking students to identify brightly colored candies by viewing them under different color illumination. Although the best results were from higher priced key-tag LEDs, inexpensive LED key-tags performed acceptably.

##### *Hit the Target: the Geometry of Reflection*

This laser target “game” was adapted from similar experiments from instructional materials developed by the NSF ISE grant Hands-On Optics: Making an Impact with Light [6] and University of New Mexico Science Inquiry Through Optics [7]. To introduce this activity, participants reviewed how to use measuring devices (protractors) to quantify what they notice about reflections. For teachers, they will learn that the angle of incidence equals the angle of reflection. For some students, they may not understand the terminology but they will be able to visualize the concept. We used inexpensive plastic mirrors and protractors.

After demonstrating an understanding of this theory, the “Hit the target” game is introduced. Students will use a laser pointer and mirrors to hit a target using progressively more mirrors to add to the challenge which demonstrates their knowledge of reflection and angles. The target has a range of point values so that the students can tally their scores.

This is an important activity for students because it not only is about reflection but also is an opportunity for them to use their early understandings of angles to demonstrate how light reflects. It is also a demonstration of how to incorporate scientific numeracy into a science lesson.

#### **Results of the professional development workshop:**

Results from the teachers have been very positive. They appreciated the background knowledge and lesson plans. Some of the teachers have been reluctant to introduce the lessons in their classroom because of their own lack of science knowledge and background. We have addressed this issue by providing on-going support to teachers who attend the workshops.

For other teachers, the lack of available school funds to purchase supplies is an issue. It is easier for them to purchase a large “kit” from a known educational distributor than to piece part supplies from smaller suppliers. This leads to sometimes not having the correct supplies or spending excess money on supplies that are not needed for a particular lesson. For our lessons, the cost of supplies was minimal and in some cases, students could bring the supplies from home. For instance, toilet paper rolls could easily be substituted for the mailing tubes in the spectroscopy activity and an old CD could be stripped of its label to provide the diffraction grating. Again with the spectroscopy activity, the student supplies are inexpensive but the teachers did not have a variety of light sources readily available. Without the light sources, this activity is not as effective. Another example is the Knox® gelatin for Jell-O® Optics is very inexpensive but to purchase laser pointers for an entire class (assuming 1 pointer for



every 2 students in a class of 24) would require purchasing a minimum of 12 pointers. However, the laser pointers are used for more than one activity (the Hit the Target activity and Jell-O® Optics activity). For Hit the Target, the cost of glass mirrors is not a factor but plastic mirrors are easier to work with and safer in a classroom environment. Refer to Table 3 for a list of supplies we used for our activities.

Table 3. Supply comparison.

Exploration	High Cost Supply	Low Cost Supply
Exploring Light Spectra	Diffraction grating slides Mailing Tubes Light sources	CDs  Toilet paper tubes
Jell-O® Optics	Acrylic lenses	Jell-O® or Knox®
Magic Box	Polarizing Film	
What Color is a...	Photon microlights	LED lights
Hit the Target	Glass mirrors	Plastic mirrors

To address this critical issue, we are developing the plans for a “lending library” of supplies. These supplies would be available to only those teachers who attend a professional development workshop. This will ensure that teachers are properly trained in the use of the supplies and knowledgeable in content. The professional development workshops for teachers will be offered yearly and as teachers become trained in the material, a greater variety of interesting lessons can be presented. We have been working with Connecticut’s NSF/ATE supported Regional Center for Next Generation Manufacturing for both material support for the lending library of optics kits and marketing and support for the teacher workshops. While EASTCONN will market the workshops to the northeast region of Connecticut, with the Center’s support, we will be able to reach teachers statewide.

**Conclusion:**

The immediate result of offering optics workshops for both students and teachers will be students who are highly prepared for the light and vision portion of the Connecticut Mastery Test. Further down the road, however, by using high quality, authentic and interesting investigations, students will be interested in studying optics and there by ensure the work force for the next generation.

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