INTRODUCTION

WHAT IS *SCIENCE, OPTICS & YOU*?

Science, Optics and You is a standards-based interdisciplinary science curriculum package for elementary students and teachers through which they can explore light, color, and optics. Activities are designed to engage students in active investigation of the properties of light beginning with lenses, shadows, prisms, and color, leading up to the use of sophisticated instruments that scientists use to help them understand the world.

The materials are presented in ways that encourage the asking and answering of questions related to light and optics and that provide strategies for students and teachers to incorporate questioning into the study of science at the elementary level. *Science, Optics and You* was designed with the premise that elementary classroom science should be an integrated, multidisciplinary core subject that incorporates critical thinking skills, specific performance skills, as well as reading, writing, and communicating skills that transfer easily to other subject areas. For that reason, *Science, Optics and You* has a strong interdisciplinary component that includes language arts, mathematics, social studies, art, and history.

The *Science, Optics and You* Guidebook is made up as follows:

- **Front Materials** to orient teachers to the perspectives from which the package was developed. This section includes instructions and strategies on how to use the materials. Also included in the front section of the Guidebook are general strategies for using visual tools to construct knowledge, constructing graphs and data tables, using historical and artist vignettes to teach science, alternative methods of assessment, and other pedagogical issues.
- **Eight *Science, Optics and You* Modules**. Each of the first six modules includes activities that are grouped by concepts covered. A Student Self-Check of performance skills and concepts is included for Modules 1-6. Modules 7 and 8 are a combination of research and project ideas and activities that will enrich the experience for students who wish to go further into the study of light and optics. Practical applications are explored in Modules 7 and 8 with explanations of technology that is dependent upon an understanding of optics. There are a total of 25 activities (see Table of Contents).
- Accompanying each activity is an artist vignette and a historical vignette. Vignettes are designed to put the concept from the activity into a context that encourages further explorations. Each vignette has activities to help students explore the impact that the study of light and optics has had upon our culture. (For further discussion of using vignettes in the teaching of science, see "Art in Science" and "Using Historical Vignettes in Science."
- Each activity is cross-referenced to State Standards.
- Each activity is accompanied by Extensions that include enhancement activities in literature, reading, writing, mathematics, social studies, art, music, and history.
- References to web sites and interactive web-based tutorials.
- Reproducible Student Pages written independent or collaborative group use.
- Appendices include transparencies that enhance teachers' and students' understanding of basic concepts, an annotated bibliography of literature books recommended throughout the activities, and an annotated reference list of resource books for teachers, and blackline masters.

Using Centers to Teach Science

You are well acquainted with the use of centers, or exploration areas, in the elementary classroom. Centers that enhance the teaching and learning of science are those that encourage students to do science rather than just experience an activity. The use of learning centers to investigate different facets of a particular unit of study is a way to expose students to many different activities over a period of time.

In classrooms where one teacher teaches all subjects, a "science area" can be equipped with objects and materials that can be used all year. Materials such as magnifying glasses, rulers, tape measures, scissors, different types of containers, beakers or graduated cylinders for measuring volume, modeling clay, straws, string and other materials that are inexpensive but are used frequently can be kept in this area. Students can visit the area as time permits. If activities are available that allow students to study a problem, design ways to investigate the problem with the materials provided, and to record their results in a notebook or journal, then students are involved in doing science.

In designing learning centers, it is important that each center be as flexible as possible in allowing manipulation of materials that allow students to pose questions and seek answers. These centers may involve pencil and paper tasks or actual experiments used to test questions students may have.

It is important to remember that students will find science learning meaningful when they are allowed to raise their own questions and try to figure out answers. True inquiry-based science activities provide for this flexibility. Activities or materials and tools themselves do not help students develop their own ideas about the world. Students need to make connections among things in their lives that make sense to them. These connections may not make sense to you, but if you have provided some content, the skills to ask and answer questions, and the materials to conduct research or investigations, then students will be able to interpret knowledge in their own way and at their own pace.

If a series of centers is designed for use with a particular unit of study, the time provided at each center should allow students enough time to complete the activity, but you will need to plan activities so that each center is completed in the same amount of time. Students should be challenged, allowed adequate time to investigate, and some time to make sense of what they have learned. This could come in many different forms, graphing, making observations, or recording data in their notebooks or journals. Sharing what they have experienced at the end of all of the activities is important. By encouraging students to express what they have learned from the experience allows them to emulate the way scientists in the real world conduct their work

Scientific Inquiry

A vision for science education as stated in the national and state standards is that all students become scientifically literate as they enter the 21st Century. The *Science, Optics and You* Guidebook supports teachers as they make this happen. The guidebook contains eight modules and 25, inquiry based and hands on activities.

Inquiry based science instruction in the elementary classroom includes the processes of science: observation, inference, and experimentation combined with scientific knowledge and critical thinking skills. The students use critical thinking and scientific knowledge as they observe the natural world to develop an even deeper understanding of science. *Science, Optics and You* uses inquiry based instruction by encouraging students to develop the ability to think critically, ask questions, develop strategies to answer their questions and communicate their findings in a variety of ways. Inquiry based instruction does require that the learner have opportunities to explore the content. Then students can develop questions about the subject. This means they will have to manipulate equipment, read, use the internet, interview, ask questions of others, and document their observations to gain an understanding so they can develop questions which they can think about. Current research in teaching and learning states more information is retained when students are given opportunities, support and encouragement to explore their own questions. This type of authentic based instruction is reflected in the *Science, Optics and You* modules and activities.

Hands-on instruction is different from inquiry in the following ways:

1. Hands-on instruction does not always have a critical thinking component.
2. Hands-on instruction may not utilize the students ideas for shaping explorations.
3. Hands-on instruction and inquiry based instruction are not mutually exclusive. In other words, hands on instruction does not guarantee inquiry.
4. Hands on activities provide the students with the opportunities for exploration and manipulating equipment so further questions may be generated.
5. They provide the students with the opportunities for observing, documenting those observations, measuring, recording, interviewing or drawing conclusions. These processes may stimulate more authentic questions, which would lead the student to do inquiry type investigations.

Inquiry based instruction and hands on science instruction are opportunities for success in the elementary classroom.

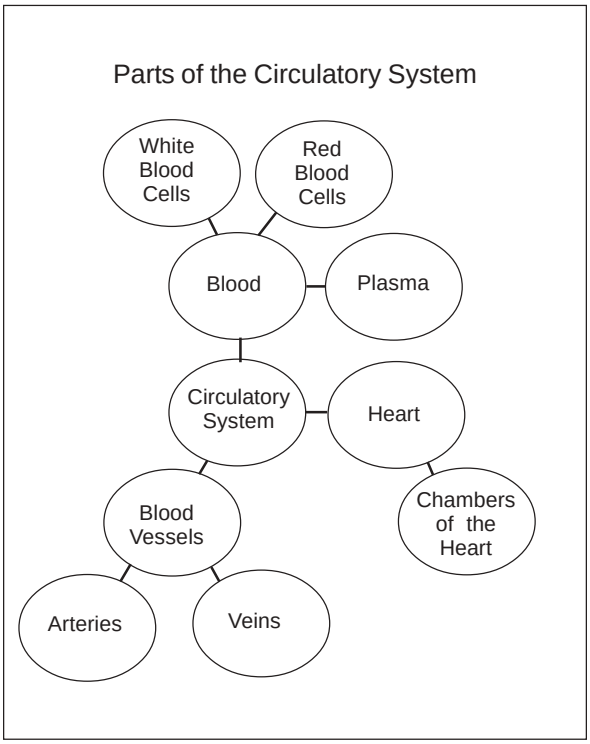
Graphic Organizers

Students and teachers use graphic organizers to help them arrange ideas in ways that make sense to them. Graphic organizers can be powerful tools to create visual pictures of information to help students see patterns and relationships. It has been said that a picture is worth a thousand words. This is especially true for graphic organizers. A good graphic organizer can facilitate a holistic understanding of complex concepts by illustrating at a glance the key parts of the whole and their relationships. Graphic organizers are particularly useful as prewriting tools for students to use for organizing their thoughts.

There are many types of graphic organizers. They include webs, Venn diagrams, matrixes, concept maps, and others. The type of organizer to be used depends on the nature of the relationships that need to be illustrated. The following are some examples of graphic organizers and descriptions of how they can be used.

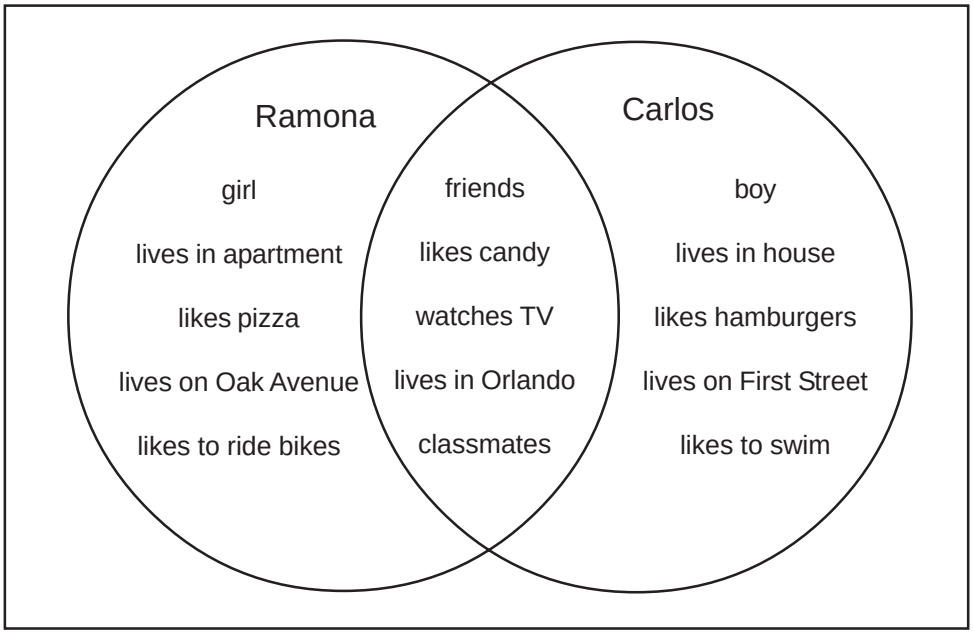
Webs

Webs are used to describe a central idea. It could be a thing, a process, or a concept. Webs are based on the thought process of identifying a main idea then its attributes or functions. In language arts they could be used to analyze the traits of main characters in literature. In mathematics they could be used to identify attributes of geometric shapes. In social studies students can use webs to analyze cultural traits. In science they can be use to identify properties of objects. Webs are particularly effective visual tools for brainstorming sessions with your students.



Venn Diagrams

Venn diagrams, developed by John Venn of Cambridge University, are used to describe and compare two or more things in terms of identifying attributes that are similar and different. Venn diagrams consist of intersecting circles that illustrate how, things, people, places, events, or ideas are alike or different. They identify and isolate those characteristics that are shared and those that are not shared.



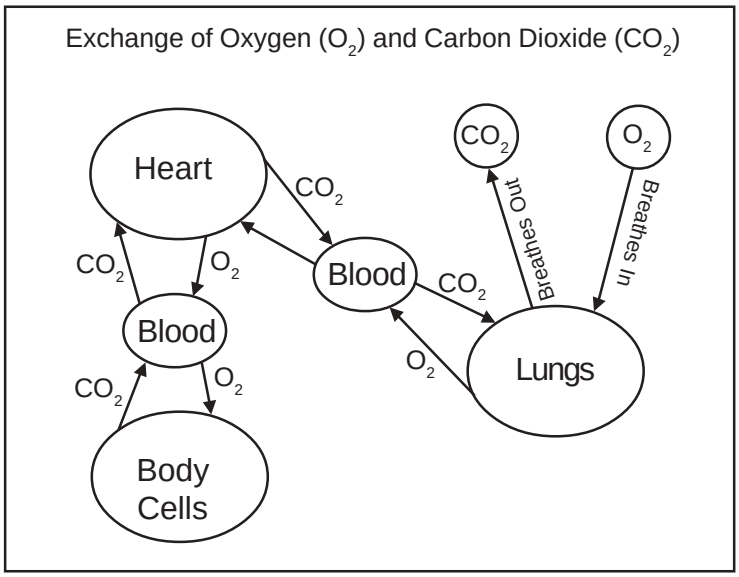
Matrixes

Matrixes are essentially tables with rows and columns that are used to show similarities and differences between two or more things. Matrixes are particularly useful for comparing many things and many attributes at the same time.

Student	Height	Weight in lbs.	Resting Heart Rate Breaths Per Minute	Quiet Breathing Rate Beats Per Minute
Amanda	4’11’	103	85	22
Carlos	4’10”	101	87	24
Ramona	4’8”	94	84	21
Jesse	4’10”	96	86	23
Monica	5’ 0”	108	85	22

Concept Maps

Concept maps are special types of webs used to map, organize, or describe the thinking process and complex relationships. Like simple webs, concept maps are used to identify related concepts and subconcepts. However, with a concept map, the links between the various cells are labeled to describe the nature of the relationships. Arrows can be used to describe the direction of the relationships. The relationships between concepts can be read like a sentence. These additional features make concept maps useful and effective in graphing relationships, which are complex.



Graphs

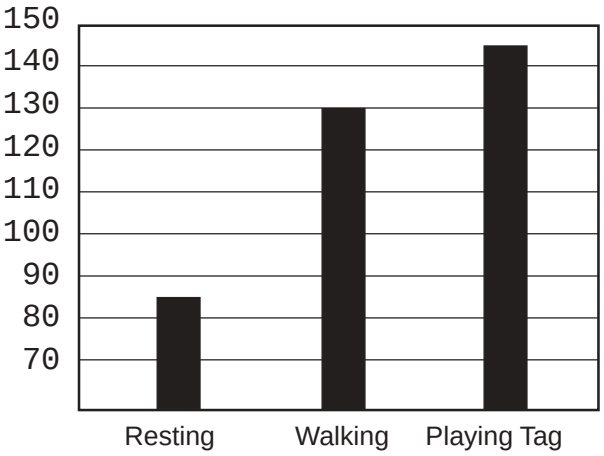
Competence in graphing skills is necessary for a number of SCIENCE-U activities. Students will be asked to use the tools of data analysis for recording, managing and displaying information (MA.E.2.2). They will be given opportunities to learn to use graphs as tools to create pictures of relationships.

One of the skills needed to construct graphs is organizing data in tables. Organizing data into tables helps your students to see patterns in the data and makes it easier to construct graphs.

Constructing Data Tables

When elements of an observation are recorded, the measurements made are called data. Measurements of time, temperature, volume, and rates are examples of data. There are no absolute rules for constructing tables of data. However, the manipulated variable is usually recorded in the left column and the responding variable is recorded in the right column. A manipulated variable is the one the experimenter changes in order to observe a response to the change. For example, the data table below is a record of measured heart rates after a variety of activities. The manipulated variable is an activity and is recorded in the left column. Heart rate is the responding variable and is recorded in the right column.

Activity	Heart Rate (BPM)
Resting	85
Walking	130
Playing Tag	145
Playing Basketball	170
Playing Soccer	180



Constructing Bar Graphs

Using a well organized data table makes constructing a bar graph much easier for your students. Students can use the information to construct a bar graph similar to the one below based on our measurement of heart rates data table. Students can use graph paper to construct the bar graph. The first step is to label the axes of the graph. The convention is to use the horizontal axis for the manipulated variable and the vertical axis is used for the responding variable. However, these may be reversed. The FCAT recognizes either way of structuring the graph as acceptable.

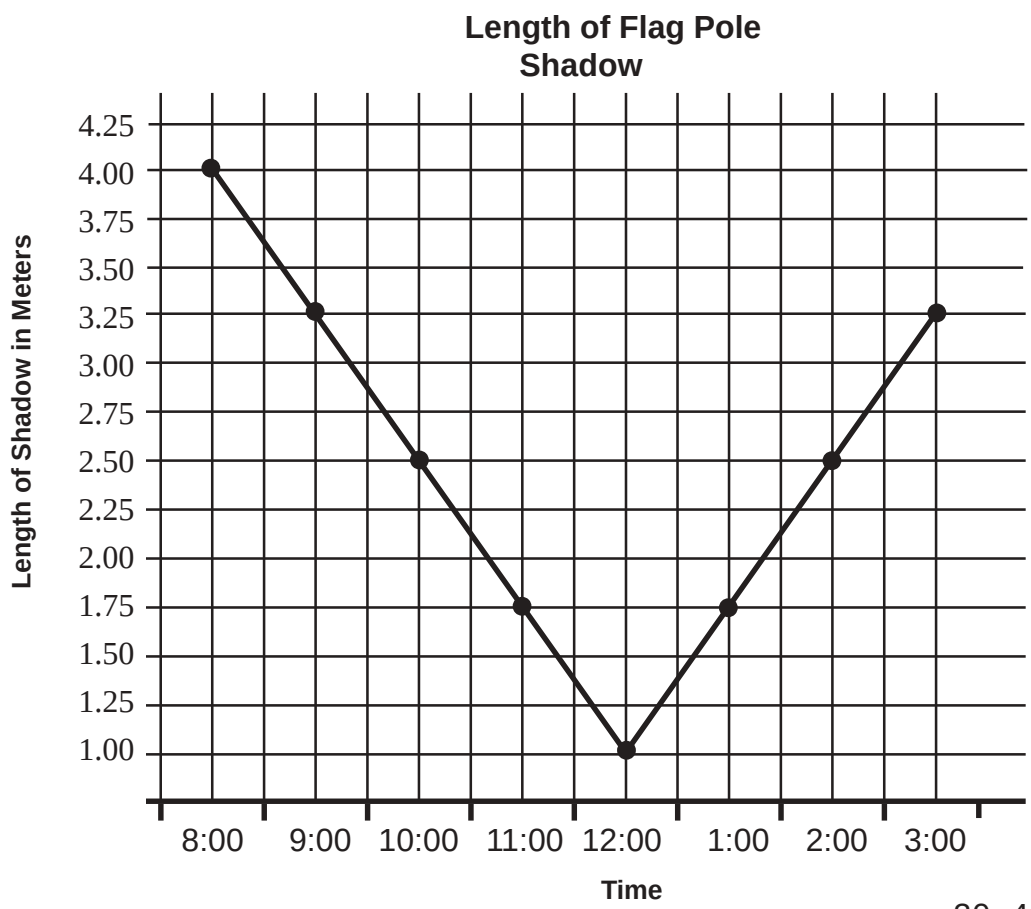
The next step is to determine an interval scale that is appropriate for the data to be graphed. In the case of heartbeats per minute, an interval of 20 beats is appropriate for illustrating changes and trends. The final step is to plot and draw bars with the designated lengths.

Constructing Line Graphs

A line graph is the best way to represent a continuous change in data. For example, a line graph might be used to show how the length of a flagpole shadow changed from one hour to the next during the day. Students would construct a data table as shown in the example. Graph paper should be used to construct the

line graph. The axes are drawn and labeled and appropriate intervals indicated as in the example. Points are then plotted to represent the two related sets of data, and a line is drawn to connect the points. If measurements of the shadow were made every hour, these points would be plotted and straight lines drawn between the points. There is an assumption with a line graph that even though the only real data points are those that are plotted, the line between points represents implied data. In the example, a shadow did exist at all times, and its length did not jump or drop from one plotted value to the other. It changed continuously and gradually as suggested by the graph. Therefore, a student could use the graph to infer the length of the shadow at times other than when measured.

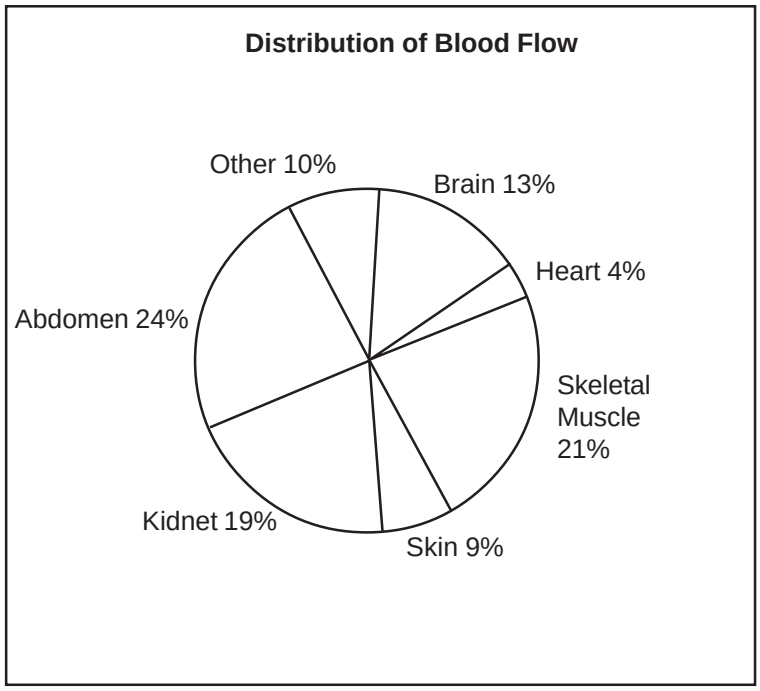
Time	Length of Shadow in Meters
8:00	4
9:00	3.25
10:00	2.50
11:00	1.75
12:00	1
1:00	1.75
2:00	2.50
3:00	4



30.48cm = 1ft

Circle Graphs

Circle or pie graphs are used when a total amount has been divided into parts and the interest is in the ratio of each part to the whole and not so much in the particular quantities. For example, the circle graph below shows a comparison of the amounts of blood flow to various parts of the body. Pie graphs can be made from computed percentages. To do this the numbers in each category are added to form the total or whole. By dividing each of the parts by the whole with a calculator, numbers between zero and one will result. If rounded to hundredths, these numbers are now percentages of the whole. Check that the total is 100 percent since rounding may cause some error. Using a compass, ruler, and protractor a circle graph can be constructed. This requires an understanding of the relationship between percentages and the degrees of a circle. Each 18 degrees of a circle represents 5 percent, 36 degrees represents 10 percent, 90 degrees represents 25 percent, 180 degrees represent 50 percent, and so forth. To facilitate construction, a hundredths disk can be used to construct the graph. It is worth noting that computer software programs are available to produce a variety of graphs. Circle graphs are included in almost every computer spreadsheet and graphing program.



Integrating Science with Reading and Writing

Science in the real world requires communication of research results, dissemination of information, and synthesis of findings. Included in all *Science, Optics and You* modules are opportunities for students to read and write to articulate the concepts covered in the activities. Reading and writing about issues in science stimulates thinking, encourages participation, and motivates students to become responsible consumers of information (Dickson, 1995).

Reading in Science

Reading is not necessarily limited to factual, nonfiction material because it is being done in the context of science. There is a great deal of well-crafted fiction as well as nonfiction material written for children that can enhance any science program by introducing students to alternative ways of thinking about science concepts. Different techniques are necessary for the different types of materials, however, and when reading from technical literature, it may be necessary to guide students' reading until they are comfortable on their own. Learning strategies such as outlining, concept mapping, and highlighting main ideas can be used to help students with expository reading. When in reading fiction books, with a little practice, students will quickly become adept at distinguishing between science facts and fiction. *Science, Optics and You* activities provide suggestions for both fiction and nonfiction books which can be used to enhance activities, extend student thinking, and reinforce concepts. *Science, Optics and You* activities also include reading experiences that are geared to address specific reading benchmarks of the Florida Sunshine State Standards, and to prepare students for the types of challenges found on the FCAT.

Writing in Science

Being able to share results and ideas with others through writing is a dynamic process that happens every day in science. The portrayal of science as a body of information or a collection of facts to be memorized precludes writing understandable research reports, readable biographies, nonfiction accounts of scientists, or fictional stories. Writing of any sort extends students' learning of science as they articulate concepts. Further, presenting results of an experience or knowledge to others requires a great deal of confidence, which can be gained from believing you have accurate information as students expand their reading experiences.

Included in *Science, Optics and You* activities are opportunities for students to write about what they have learned in a variety of ways. While research writing is an important science skill, children often resist when assigned to write reports and respond with sterile and stilted compositions (Matz, 1990). Therefore, *Science, Optics and You* includes writing activities that add the elements of self-reflection and creative imagination. The *Science, Optics and You* writing activities are designed to provide students with experiences that promote the effective use of the writing process consistent with standardized tests.

Journal writing and reflective writing are two ways for students to clarify their thinking and articulate science concepts. These techniques also provide the teacher with unique insights into how students learn and what the are learning. Throughout the *Science, Optics and You* modules students are encouraged to maintain Science Notebooks. The Science Notebook is a vehicle that encourages students to take notes, express themselves, clarify ideas, criticize their own thinking, and reflect on ideas. Science Notebooks also provide a record of data collected, questions to be answered, and serve as a ready reference for subsequent inquiries.

In addition to the Science Notebooks, teachers are encouraged to offer students varied writing opportunities such as:

- Composing letters and/or email to other students in the school or in remote locations to share science-related experiences, to request information from scientists, to write persuasive letters about scientific or social issues, or to contact legislators and public figures who affect public policy.
- Developing picture or easy reading books written and published by students to introduce scientific concepts to younger students.
- Creating poems and skits about the topic being studied, to personalize the information or concept learned through the expressions of the affective domain.
- Writing stories using a variety of techniques and representing a variety of genres; for example, science fiction or fantasy based on scientific ideas, life in the future, life and creatures from prehistoric times, life in a different environment, imaginary creatures and distant worlds.
- Other writing opportunities include creating web pages, fact books, guidebooks, manuals and video productions, writing newspaper or magazine articles, editorials, interviews, dictionaries, technical reports, posters, and advertisements. These writing experiences will draw students into the inquiry process and lead to understanding and internalizing of new ideas.

Assessment

The assessment portion of *Science, Optics and You* is designed to improve teaching and learning rather than supply teachers with assessment for monitoring. However, how you opt to use this section is a decision that only you can make based upon your school and classroom needs and the individual personality of each class.

Each assessment task in *Science, Optics and You* has been designed to conform with National Science Education Assessment Standards. Formative and summative assessments are addressed. It is assumed that you will know best which task to choose for which purpose at different times. *Formative* assessment is used to gather information so that you can plan future work for your students. Formative assessment is a diagnostic tool in that it helps the teacher decide how to proceed. *Summative* assessment, on the other hand, is used to determine where the students are within a certain continuum. Summative assessment answers the question, "How far have my students come?" It is the type of information that you would provide to parents—a summary of the child's progress.

Each task is accompanied by suggestions to help you determine whether the students you teach with their specific and particular needs, abilities and interests, have successfully met the goals for the assignment. What have students learned? How did they learn it? Why did students find it important? What connections have students made with other disciplines? Where can students go from here?

Types of Assessment:

Performance assessment refers to tasks that students engage in for a long period of time and do something that results in a product. Performance assessment is embedded in each activity. Each time you ask a student to solve a problem using the concepts and content in an activity, that student is required to demonstrate a knowledge that goes beyond memorization of facts for a multiple-choice test. If students measure the temperature of water they are demonstrating that they are proficient in using a thermometer. Taking a

measurement to show proficiency in measurement is a performance assessment. When you look around your classroom and students are working together simulating real-world decision making situations, this is also performance assessment. Other examples of performance assessment tasks include brainstorming, using content and concepts in unstructured ways, relating science concepts to other areas of study, using multiple methods of communication to present science concepts to others, reading and writing about science, or analyzing data in a coherent way.

Any method of collecting work in an organized fashion as evidence of learning can be considered a "portfolio." Portfolio assessment can take many forms. For example, the Science Notebook that the students maintain for a series of investigations can be considered a portfolio since it will contain most of the information and analysis required for each activity.

Authentic assessment simply means that the students are thinking like and doing tasks like scientists do. In the case of the Science Notebook, keeping a log of information is something scientists do. In addition, since the students know the purpose of the notebook and its role in the activity, keeping the notebook is an authentic task.

Assessment Choice

Current theories about assessment in classrooms encourage teachers to give students choices about how they can best display their newfound knowledge. This is not to say that with each assignment, students should be allowed to do whatever they please; rather, students need a repertoire of resources from which to select the one that allows them to best demonstrate what they have learned. Certainly there are times when you decide what is to be completed, how, and when. By suggesting a variety of ways in which students can display their knowledge, you enable students to select the best assessment tasks and display strategies. By making a conscious selection of one option from an array of tasks, the student frequently takes ownership of that particular assignment

What are your students expected to know?

Science, Optics and You expects that your students will use certain skills or will acquire those skills as they complete each Module. Many students come to the the classroom with a repertoire of problem-solving and critical thinking skills. However, it cannot be assumed that all students have these skills when they enter the science classroom. It is advisable to determine at the beginning of the school year those learning skills that you will want to develop. Using *Science, Optics and You* to develop some of these skills is an option, but you will want to choose your groups carefully and rethink your expectations if these skills are being introduced. Skills listed here are not subject-specific and should increase students' opportunities to be successful in all content areas.

Brainstorm: Students clarify ideas in either small or large groups without judgments being made as to "right" or "wrong" answers. Groups generate a large number of ideas from which to choose. Brainstorming encourages different perspectives and allows each person to contribute without question.

Draw conceptions: If students have never been asked to draw their idea of something, they may need some guidance. In the case of *Science, Optics and You*, students will draw, for example, their idea of how rainbows are formed. The drawing supplies a permanent document that can be revisited at a later time, added to, or subtracted from. In some cases, students are not able to articulate their ideas, but can draw them. When asked to explain their drawings to you or another student,

students can often clarify their thoughts more easily.

Group roles: Regardless of how you choose to design your groups (you choose, students choose, same groups for all activities, or rotating roles in static groups, for example), students should have assigned roles. The roles represent tasks that need to be completed but include some discussion of the fact that the defined tasks are not the sole responsibility of one person; rather, the group maintains responsibility for the total product. Examples of group roles are: recorder, spokesperson, materials manager, and timekeeper. These roles could rotate on a regular basis or could be chosen by you based on identified areas in which students excel or based on areas in which you believe students need more practice.

Articulate ideas and reach group consensus: In each *Science, Optics and You* activity, you are asking your students to make decisions as a group. This is a skill that many elementary students may not have. You will need to guide some groups with a discussion of decision making and listening skills. You may need to speak about leadership versus authoritative behavior and leadership versus dominance. Although students may have done groupwork previously, they may be just getting to a point where true collaboration is a possibility.

Critical analysis skills: Some skills that will be necessary to develop through these Modules are distinguishing between similarities and differences, being able to compare and contrast, identifying the main idea in a paragraph or article, and distinguishing between fact and fiction.

Group work/Cooperative Learning

Science, Optics and You is designed to support students working in pairs or groups of four. How groups are chosen is up to you. Students will realize after several experiences working in groups that working in a group is not working *near* other people, but *with* other people.

There are several ways to set up for group work: you choose the groups based on areas of expertise or areas in which students need practice; students choose their own groups for the maximum comfort level; or groups are chosen randomly. Regardless of how you decide to implement the groups, there is some preliminary discussion that is necessary about your expectations, group roles and responsibilities, and ultimately what is expected of the final product. In the case of the Science Notebooks, it is imperative at the start of *Science, Optics and You* that you make it very clear that the Notebooks are individually completed, but based on the collaborative work.

Learning Styles

Each person has a way of learning and presenting evidence of that learning. A learning style should not be confused with multiple intelligences as presented by Howard Gardner. A learning style is a way of approaching learning that is usually applied to all content. Some students learn well by listening and repeating information orally; others demonstrate what they have learned by creating artwork. Still other students can incorporate science concepts into creative writing material, while some students do well with graphic organizers such as charts, graphs and concept maps. There are students who prefer a multiple choice-type test to demonstrate what they have learned. More and more frequently students create multimedia projects to display their learning. It is our intention that these assessment materials provide you and your students with enough choices to accommodate the learning styles of all the students that are in your classroom.

Rubrics

A rubric is part of the process of scoring student work by determining a standard of performance based upon your class. (I refer you here to the National Science Education Standards discussion of assessment.) Setting up a rubric for each assessment task serves several purposes including clarifying teacher expectations and providing students a clear guide to measure how well they are meeting these expectations. There is no question about whether a student is successful if there is a clear understanding of what is required when the task is assigned. An example of a rubric for a diagram about rainbows might be:

A. The diagram includes a prism or a water droplet acting like a prism, has a title, illustrates white light being broken into the colors of the visible spectrum, and has the colors of the spectrum represented in the correct order.

B. The diagram includes all a prism or a water droplet acting like a prism, has a title, and illustrates white light being broken into the colors of the visible spectrum.

C. The diagram includes a prism or a water droplet acting like a prism, a title, and illustrates white light as different colors after it hits the prism or water droplet.

D. The diagram does not include a prism or a water droplet acting like a prism and does not indicate in any way that white light is actually composed of the colors of the visible spectrum.

F. The diagram includes a drawing of a rainbow.

To encourage students to further take part in self-evaluation, you could have the class create the rubric. Discussing the criteria of a certain task helps students clarify what they need to do to be successful. Being certain that your expectations are clearly defined for students is, in many instances, the key to their success or failure. Further, it makes your job easier, since many questions have been addressed ahead of time. Students will not come back to you later with questions about why they got a certain grade.

An excellent resource for further information on assessment in science and mathematics classrooms is *Science Assessment in the Service of Reform* edited by Gerald Kulm and Shirley M. Malcom, American Association for the Advancement of Science, 1992. ISBN 0-87168-426-8.

Current Issues

Any time students make the link between what is happening in the science class and real life it is a victory for the science teacher. A simple comment such as "I saw a rainbow yesterday on my way home and I know how it is made," becomes a teacher's badge of honor. Using magazines, videos, television, and newspapers in the classroom is a valuable technique especially in science. Scientific research and development laboratories announce new discoveries every day. Sometimes in the course of just one school year a discovery or invention is announced and soon thereafter is repudiated or worse rejected as fraudulent. Students are more aware than ever of issues such as AIDS, cloning, space travel, and environmental problems. Tapping into their natural curiosity about such issues can alleviate fears and answer questions. Reading expository material is a skill that is rarely "taught."

Interdisciplinary/Integrated Application

Science, either in the classroom or in a research laboratory, is not done in isolation. Current events, history, literature, art, and music influence even scientists who have a very specific area of interest. To study science in a classroom that is devoid of these other areas of interest is not only artificial but also sends the wrong message to middle level students. Regardless of the science discipline being studied, it is imperative that students begin to make connections between what they are studying and real-world applications. Using the knowledge gained in their science classroom to enhance the study of geography or language arts reinforces the interdisciplinary nature of science. When students find relationships between and among the subjects that they study they are more likely to find intrinsic value in the knowledge they are gaining.

Misconceptions in Science

One of the most difficult jobs a teacher has is determining what students know, what they think they know, and how to use that understanding to facilitate further understanding. Many students come to science classrooms with misconceptions about the world, how the world works, and where we fit in. This is partially due to misinformation, misunderstanding, and attempts to understand concepts that are too big to even contemplate without good models. Using misconceptions as a jumping off place for science exploration can be a good strategy because the student is already comfortable with the idea behind the misconception. Correcting misconceptions requires that students must clarify concepts and then find a replacement for the mistaken idea.

Science Fiction

Distinguishing fact from fiction is a skill previously mentioned as necessary in the science student's repertoire of competencies. As students attempt to determine what parts of a science fiction story could be true and the parts that could not be possible, they begin to describe what they know. In order to identify and defend the factual portions of a science fiction story, students need to find evidence to back up their claims. Science fiction helps students discover the effect that science has on their lives and how science could affect the future. Science becomes much more than a collection of facts. It takes on new meaning as students try to imagine the future. This requires that students take a look at society today in order to imagine how it will be in the future. Current technological advances form the basis for inventing new modes of transportation, new ways of getting information, and ways of understanding new scientific research breakthroughs (for example, cloning).

Using Historical Vignettes in Science

In *Science, Optics and You*, historical vignettes are used to enhance each activity. These vignettes serve to explain some of the scientific contributions that have been made by scientists and how these scientists were either influenced or limited by the culture of the time. All of the historical vignettes have extensions that encourage writing, additional research or serve as springboards for group or class discussions. Historical vignettes may be about the lives of scientists who have increased our understanding of science. They may be used as teacher background information or for "story-telling." Stories told by teachers often capture the imagination and interest of students, and make the learning experience more meaningful.

According to *Science for All Americans* (1990), knowledge of the way science works is an important component of scientific literacy. Science requires creativity, imagination and insight. Students should be encouraged to think about what is going on and use their creativity and imagination to explore concepts in science. The idea of vignettes may be extended so that

they tap into the creativity and imagination of students. Instead of using the vignettes provided in *Science, Optics and You*, students may create and present their own vignettes to the class as multimedia presentations or skits, including period costumes. Vignettes could be assigned to different groups in the class, and students in these groups could extend the impact of their historical vignette by producing a bulletin board as a "Scientist of the Week" theme. Students will find a list of scientists to research at http://micro.fsu.edu/optics.

Using Artist Vignettes in Science

Many concepts in science would be difficult to understand if drawings, diagrams and models were not used. For this reason in *Science, Optics and You* there are many activities involving art and science. Included in each of the activities is an Artist Vignette. These vignettes encourage students to make connections that exist between science and art. All of the artists featured in these vignettes have used some of the principles or applications of optics including light, lenses, mirrors, color, photography, shadows, or optical illusions. For example, in Module 3: Activity 7, Mirrors and Multiple Images, the Artist Vignette is about Leonardo da Vinci. In this vignette a discussion of possible reasons for him using "mirror writing" in his notebooks is included. This leads directly to an activity in which students are encouraged to try mirror writing and then use the mirrors in their *Science, Optics and You* package to read their messages.

Another use of art in the *Science, Optics and You* modules involves students drawing or making diagrams as methods of explaining data or as a way of problem solving. For example, in Module 4, Activity 8: Light, Prisms and the Rainbow Connection**,** students are encouraged to draw a picture that illustrates how to produce the color spectrum by using a flashlight and a prism. This technique reinforces what the students have discovered in the laboratory activity. Diagrams can also be used as a form of performance based assessment, or may be placed in students' portfolios as evidence of skills mastered.

Artist Vignettes analyze techniques used by certain artists and encourage students to model those techniques. The use of primary versus secondary colors, Pointillism, Impressionism, and the application of photo micrography are techniques that manipulate color, and light. For students the use of Artist Vignettes helps them realize that science is not an isolated subject, but is interwoven with other areas of study such as art, math, history and language arts.

Researching in Science

By the end of the fifth grade, students should support their statements with facts found in books, articles and databases and be able to identify the sources used (Benchmarks for Scientific Literacy). For this reason, students need to be comfortable with using a variety of media to find information. In *Science, Optics and You*, there are many opportunities for students to research topics about Optics. Whether students use library books, magazines, newspapers, encyclopedias, videos, or the Internet, they may need some assistance with how and when to use each of these forms of media.

Before beginning research on a particular topic, students need to know where to look. Recognizing the type of information they need, whether it is facts, opinions, news reports, or historical information from primary sources, knowing where to look will make their task easier. If students are searching for information on some current event, then a reliable newspaper like the *New York Times* or the *Washington Post* will be a useful source. Checking the date of publication is as important as the choosing which publication to use. It is important for students to be aware of the date

that any article was published. Materials, especially science materials, become outdated quickly and may not be current enough to be useful. On the other hand, if a student is looking for an historical perspective, the date may not be of primary importance.

Here are some sample citations taken from the APA Publication Manual:

> Book: Author, I. (date). Title. City, State: Publisher.
>
> Article in a magazine or newspaper. Author, I. (date). Title. Journal, Volume #, page number.

Internet sources can be very timely and very useful, but they should not be the only source of information that the students use. There are several caveats about using the internet with any level students.

- Check all websites before recommending them to students or using them in class. This includes all links from that website.
- Students need to understand that they must cite the website just as they would give credit to an article or book. Here is an example of how to cite on-line information:

  > Author, I. (date). Title of article. [On-line]. Available: Specify path.

- Forms for citing on-line information can be found in Li and Crane's (1993) *Electronic Style: A Guide to Citing Electronic Information.*
- Information and graphics found on a website is usually copyrighted material. It is technically illegal for students to print out material from a website and claim it as their own.
- Material found on websites cannot be used for other purposes unless the creator of the website gives his or her permission.
- The source of information found on websites should be checked carefully. The information is only as reliable as the source. Students should be told that just because they find something on a website does not mean that it is dependable.

How to Design and Use Discovery Centers

You are well acquainted with the use of centers, or exploration areas, in the elementary classroom. Centers that enhance the teaching and learning of science are those that encourage students to do science. The use of learning centers to investigate different facets of a particular unit of study is a way to expose students to many different activities over a period of time.

In classrooms where one teacher teaches all subjects, a "science area" can be equipped with objects and materials that can be used all year. Materials such as magnifying glasses, rulers, tape measures, scissors, different types of containers, beakers or graduated cylinders for measuring volume, modeling clay, straws, string and other materials that are inexpensive but are used frequently can be kept in this area. Students can visit the area as time permits. If activities are available that allow students to study a problem, design ways to investigate the problem with the materials provided, and to record their results in a notebook or journal, then students are involved in doing science.

In designing learning centers, it is important that each center be as flexible as possible in allowing manipulation of materials that lead students to pose questions and seek answers. These centers may involve pencil and paper tasks or actual experiments used to test questions students may have. It is important to remember that students will find science learning meaningful when they are allowed to raise their own questions and try to figure out answers. True inquiry-based science activities provide for this flexibility. Activities or

materials and tools can help students develop their own ideas about the world by making connections to things in their lives. These connections may not make sense to you, but if you have provided some content, the skills to ask and answer questions, and the materials to conduct research or investigations, then students will be able to interpret knowledge in their own way and at their own pace.

Students should be challenged, allowed adequate time to investigate, and provided time to make sense of what they have learned. This could come in many different forms: graphing, making observations, or recording data in their notebooks or journals. Sharing what they have experienced at the end of all of the activities is important. By encouraging students to express what they have learned from the experience allows them to emulate the way scientists in the real world conduct their work.

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