Curriculum Units by Fellows of the Yale-New Haven Teachers Institute
1998 Volume VI: Selected Topics in Contemporary Astronomy and Space Science

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Exploring the Moon: A Curriculum Adapted For Use With Blind and Visually Impaired Students

Curriculum Unit 98.06.06
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Man first landed on the Moon on July 20, 1969 and last walked on the lunar surface in December l972. In fact, the Moon is the only extraterrestrial body to be visited by humans and it is the only body from which rock samples have been returned to Earth. The history of man's exploration of the Moon in the Apollo program and the knowledge we have gained about the Moon from these voyages will be the focus of this curriculum.

This curriculum will allow students:

1. to study the Moon in detail including the Moon's origin, geology, and landscape
2. to study the history of man's exploration of space including the voyages of the Apollo missions to the Moon
3. to provide opportunities for students to be active participants in a class project exploring the Moon

This curriculum was developed for students in 4-6 grades who are attending regular and special education programs in the New Haven Public School system. In addition, this curriculum is adapted to assist visually impaired and blind students in accessing the materials and information necessary to work on this topic. It is hoped that the adaptations suggested will also help teachers understand how future science lessons can be modified for students with visual impairments.

The classroom activities proposed will promote problem-solving, communication skills, and teamwork as well as scientific knowledge. It is believed that the knowledge and understanding gained from this project will assist students as they attempt to comprehend problems on a wider or global scale.

OUR SOLAR SYSTEM

The Sun is a 5 billion year old star that is the center of our Solar System. The Sun is nearer to Earth than other stars and so the Sun seems enormous to us. However, compared to other stars it is actually of average size and age. Planets, including Earth, move around the Sun. At the same time, some of the planets have one or more Moons circling around them. Earth has only one Moon---a natural satellite that is large enough and close enough to provide light to Earth at night. The second brightest object in the sky after the Sun, the Moon, produces no light of its own, but it instead reflects sunlight.

Earth's Satellite

Planets are usually much larger than their Moons and hundreds to thousands of times more massive. The Earth and its Moon, however, are an unusual duo since they are similar in size. The Moon is about 2,160 miles in diameter or approximately a quarter of the diameter of the Earth. The mass of the Moon is only about eighty-one times less than the Earth. Due to its size and composition, the Moon is sometimes classified as a terrestrial "planet" along with Mercury, Venus, Earth and Mars.

There is no atmosphere on the Moon and no magnetic field, therefore, the Moon's surface is exposed directly to the solar wind. Therefore, its surface is not constantly being worn away by wind or rain erosion and probably hasn't changed except for the rare impact of meteorites in more recent times.

History of Moon:

Over the centuries, scientists have developed many theories on how the Moon was formed. However, prior to the study of the Apollo samples brought back from manned flights to the Moon, there was no consensus about its origin.

The Principal Theories:

> l. Co-accretion : This theory asserted that the Moon and the Earth formed at the same time from the Solar Nebula

> 2. Fission: This theory asserted that the Moon split off of the Earth and went into orbit

> 3. Capture: This theory held that the Moon formed in another part of the Solar System and was later captured by the gravitational pull of the Earth.

After studying the lunar rock and soil samples, scientists know that these theories are incorrect. Instead it is now widely believed that the Moon was formed around the same time as the Earth. Thus the impact theory was developed.

> 4. Impact Theory: New and detailed information from the Moon rocks led to the theory that when the Earth was young and developing it collided with a very large object . The core of this body became part of Earth while the lighter material shot into space and began orbiting around until it

collected to form the Moon.

The Moon's Effect On Earth

The Moon has a great influence on the Earth in part because of its large size in relationship to the Earth. The Earth exerts a strong gravitational pull on the Moon. The moon's gravitational attraction is stronger on the side of the Earth nearest to the Moon and weaker on the opposite side. Tides are caused by the pull of the moon's gravity on earth's surface. Land is too firm to respond noticeably to this pull, but water stretches toward and away from he Moon. On the earth's surface we see two small bulges, one in the direction of the Moon and one directly opposite.

Astronomical Data

The distance from the Earth and Moon varies between 221,000 and 253,000 miles in a one month period due to the fact that the Moon moves around the Earth in an elliptical orbit.

The Moon orbits Earth showing a different phase, or lighting condition on its surface, at various times of the month. Each month the Moon goes from anew Moon, to a crescent, through to a full Moon, and then back again. Since the Moon orbits the Earth about once a month, these phases were used in ancient times as a basis for a lunar calendar.

When the Moon is on the opposite side of Earth from the Sun, the side we see is all lit. This is known as the "full Moon." When it is on the side of Earth that is near the Sun, the lit side is away from us and we don't see the Moon. In between those periods, the Moon is partially lit.

The Earth is moving in its orbit around the Sun in the same direction as the Moon and so the time needed to return to the same position is 29 days, 12 hours, 44 minutes, and 2.8 seconds. This is known as the synodic month and is the time interval that elapses between two successive full Moons. Because the rotation period of the Moon and the revolution period around the Earth are the same, the Moon shows the same hemisphere (called the near side) to Earth at all times. Conversely, one hemisphere is forever turned away from us (the far side.) Before the space age, the "far side" of the Moon was unknown. In October l959, The Soviet

LUNAR 3 spacecraft was the first to map the far side of the Moon showing craters, mountains, and lunar seas.

Eclipses

Typically, as the Moon travels through the sky and approaches the Sun's position, it goes a little bit above or below the Sun. At times, however, it cuts right across the Sun and hides it for a few minutes. This is a solar eclipse.

On the other hand, sometimes, when the Moon is full and on the opposite side of Earth from the Sun, it passes through the earth's shadow. When the earth's shadow falls on the bright side of the Moon, it makes the moons surface dark. This is a lunar eclipse and may last several hours

STUDYING THE SURFACE

The Surface of the Moon:

It is easy to study the Moon's surface with the naked eye. Astronomers, long before modern times, have tried to understand the details they could view. Studying the moon's surface with the naked eye reveals both shadows and bright spots on the lunar surface. In 1609 an Italian scientist, Galileo, built a telescope to view objects in space and was able to see mountain ranges and craters on the Moon.

Terrain

The Moon's crust is an average of 68 km thick. Below the crust is a mantle and possibly a small core. The Moon's center of mass is offset from its geometric center by about 2 km in the direction toward the Earth. Also, the crust is thinner on the near side.

There are two primary types of terrain on the Moon: the very old, heavily-cratered highlands and the relatively smooth and younger maria. The maria comprises about 16% of the Moon's surface and is composed of huge impact craters that were later flooded by molten lava. Most of the surface is covered with regolith, a mixture of fine dust and rocky debris produced by meteor impacts.

Most of the craters on the near side are named for famous figures in the history of science such as Tycho, Copernicus, and Ptolemaeus. On the far side, craters are named for such figures as Apollo, Gagarin and Korolev.

The Moon also has huge craters on the South Pole such as Aitken which at 2250 km in diameter and 12 km deep is the largest impact basin in the solar system. Orientale, a multi-ring crater is located on the western limb.

The Moon provides evidence about the early history of the Solar System not available on the Earth. The Apollo and Lunar programs brought back to Earth a total of 382 kg of rock samples. These provide most of our detailed knowledge of the Moon. They are particularly valuable in that they can be dated. Most rocks on the surface of the Moon seem to be between 4.6 and 3 billion years old compared to the oldest terrestrial rocks which are rarely more than 3 billion years old.

The Moon has no global magnetic field. But some of its surface rocks exhibit remnant magnetism indicating that there may have been a global magnetic field early in the Moon's history.

Seas Without Water

Craters on the Moon were caused by meteorites bombarding the surface that occurred in early days of Moon. There are several dark patches on the surface of the Moon that astronomers thought were huge bodies of water. They include the Sea of Tranquillity, the Bay of Rainbows, and the Lake of Death.

Now scientists know that there is no water on the Moon and these areas are actually smooth, flat plains that formed ‹3.5 billion years ago when lava poured out from the interior of the Moon. This lava covered 15 percent of the lunar surface when it flowed into the lowlands.

Crater-Scarred Surfaces:

Most of these craters were formed when meteors rained down on the surface of the Moon. Few craters are found in the lowland indicating that the meteor impacts must have occurred before lava flowed from the moon's interior.

The bright area which covers the rest of the Moon have thousands of craters in the highlands. Some of the larger craters have mountainous edges or peaks that rise from their centers. They can be seen from the Earth without the aid of a telescope. The Moon has no atmosphere and so there is no wind or rain constantly eroding the surface. Due to lack of an atmosphere the Moon probably hasn't changed in billions of years except for the rare impact of meteorites. Therefore, the Moon provides evidence about the early history of the Solar System not available on the Earth. Samples of Moon rocks brought back to Earth help scientists look back billions of years to the early ages of the Solar System and provide information on how the Earth was formed.

Man Reaches For The Moon

Mankind has always dreamed of journeying to other worlds in space. The Moon is the only place in the Solar System that we have reached with both unmanned space probes and astronauts. Discoveries from these mission have changed our knowledge of both the Earth and Moon.

In I959, the former Soviet Union sent a spacecraft past the Moon to take pictures of the far side of the Moon which had never been seen from Earth. Later in that year, Lunar 2, a Soviet probe landed on the Moon.

The attempts by the United States and the Soviet Union to land a manned spacecraft on the Moon resulted in a flurry of scientific activity as each country attempted to gain the necessary knowledge and develop the necessary technology to win that race.

In 1961, President John F. Kennedy set the target for America to reach the Moon by the end of the decade. The National Aeronautics and Space Administration (NASA) created Project Gemini, a series of missions conducted close to Earth, to meet that challenge. The Apollo program followed setting the stage for landing astronauts on the Moon.

The Ranger, Orbiter, and Surveyor probes were the first US. spacecraft sent to the Moon. They were unmanned flights which helped to find possible landing sites for future manned flights

Apollo 8 was the first manned vehicle to orbit the Moon. Apollo 9 launched a command and service module and lunar module into Earth orbit These vehicles and equipment would be used during future lunar landings.

Apollo 10 was the final rehearsal before landing on the Moon. Astronauts separated the lunar module form the command and service module while they orbited the Moon. They flew to low altitude over the Sea of Tranquility and then re-docked successfully.

Apollo 11 lifted off the Kennedy Space Center on July 16, I969. Four days later, Apollo's lunar module touched down on the Sear of Tranquillity. Five more landings followed. The Apollo program cost $20 billion and employed a half a million people in some facet of the effort.

Man On The Moon

On July 16, Apollo 11 lifted off the launch pad at the Kennedy Space Center carrying Astronauts Neil Armstrong, Edwin "Buzz" Aldrin and Michael Collins. Four days later, Armstrong and Aldrin boarded the lunar module named the Eagle and flew to the landing site in the Sea of Tranquility. Michael Collins remained in the Command Service Module.

Aldrin reported the touchdown on to the lunar surface by announcing "Tranquility Base here. The Eagle has landed." The astronauts readied themselves for stepping on the Moon by putting on spacesuits and life support systems. And then Neil Armstrong passed through the hatchway and stepped down a ladder to the lunar surface. As Neil Armstrong placed his foot on the Moon's surface-- he spoke the words heard around the World, "That's one small step for a man, one giant leap for mankind."

Armstrong and Aldrin spent four hours on the surface of the Moon planting a flag, setting up experiments, and placing a plaque to commemorate the occasion. They also collected 50 pounds of lunar soil and rock samples to bring back to Earth. The two astronauts then reboarded the Eagle and blasted off the Moon to successfully dock with Collins in the CSM. After an eight day mission they headed back to Earth and splashed down in the Pacific Ocean.

Five other missions landed on the Moon. In a later mission, astronauts used the lunar roving vehicle, a ten-foot-long cart that allowed them to explore more of the lunar surface. Apollo 17 was the last manned fight to the Moon.

The Apollo program was very expensive but provided many scientific gains. The entire Apollo program cost $20 billion. It allowed a dozen astronauts to explore over 60 miles of the lunar surface collecting 850 pounds of rock and soil. Over 30,000 photographs were taken. In addition, over a half million people were employed in some facet of the this effort.

LEARNING FROM APOLLO

Exploration of the Moon continues to provide us with knowledge about our universe both past and present. In addition, it supports the development of new technologies and scientific discoveries. Although manned flights to the Moon have been discontinued, NASA continues to explore the lunar system with robotic explorers. The Moon was extensively mapped in the summer of l994 by the spacecraft Clementine and Lunar Prospector is now in orbit around the Moon.

ICE ON THE MOON

On March 5, l998, it was announced that data returned by the Lunar Prospector spacecraft indicated that water ice is present both the north and south lunar poles.

This confirms earlier reports in November l996 by the Clementine probe that ice was present at the south pole of the Moon. The Lunar Prospector indicates that ice appears to be mixed in with the lunar regolith (surface rocks, soil, and dust) at low concentrations of 0.3 to 1 percent. The ice appears to be spread over 3,600 to

18,000 square miles of area near the north pole and 1,800 to 7,200 square miles around the south pole. It is estimated that the ice is distributed in a layer from 0.5 to 2 meters deep, giving an estimated total volume of ice of 11 to 1300 million tons although these models can be off considerably.

How Was The Ice Detected?

In those areas that are permanently shadowed pictures cannot be obtained. The Clementine spacecraft searched for ice using an investigation known as the

Bistatic Radar Experiment.

The Lunar Prospector, a NASA Discovery mission, was launched into lunar orbit in January l998. The Lunar Prospector carried equipment called the Neutron Spectrometer designed to detect minute amounts of water ice at a level of less than 0.01%. the Neutron Spectrometer can detect water to a depth of about half a meter. The instrument concentrated on areas near the lunar poles where it was thought water ice deposits might be found.

The Neutron spectrometer looks for so-called "slow neutrons" which result from collisions of normal "fast" neutrons with hydrogen atoms. A significant amount of hydrogen would indicate the existence of water.

The data from the first two months of orbit show a distinctive 3.4 percent signature over the north polar region and a 2.2 percent signature over the south pole. This is a strong indication that water is present in both these areas.

How Can Ice Survive on the Moon?

The Moon has no atmosphere, so any substance on the lunar surface is exposed directly to vacuum. Thus the Moon's low gravity cannot hold gas for any length of time. This means that ice will rapidly turn directly into water vapor and escape into space.

During the course of a lunar day, all regions of the Moon are exposed to sunlight. The temperature on the Moon in direct sunlight reaches about 395 degrees K or 250 degrees above zero F. Therefore, any ice exposed to sunlight for even a short time would be lost. The only possible way for ice to exist on the Moon would be in a permanently shadowed area.

The Clementine imaging experiment showed that such permanently shadowed areas do exist in the bottom of deep craters near the Moon's south pole. It appears that approximately 2300 to 5800 square miles of area around the south pole is permanently shadowed. The permanently shadowed area near the north pole appears on Clementine images to be considerably less, but the Lunar Prospector results show much larger water-bearing area at the north pole.

Much of the area around the south pole is within the South-Pole-Aitken Basin, a giant impact crater 1550 miles in diameter and 12 km deep at its lowest point. Many smaller craters also exist on the floor of this basin. Since they are down in this basin, the floors of many of these craters are never exposed to sunlight. Within these craters the temperatures would never rise above 280 degrees below zero F. Due to these temperatures any water ice at the bottom of the crater could probably exist for billions of years.

Where Did The Ice Come From?

The Moon's surface is continuously bombarded by meteorites and micro-meteorites and as indicated by the size of the craters any of these were very large objects. Many contain water-ice. Any ice which survived impact is scattered over the lunar surface. Most of the ice is quickly vaporized by sunlight and lost to space, but some ends up inside the permanently shadowed craters and remains frozen there.

Why Is Ice On the Moon Important?

The ice could represent relatively pristine asteroid material may have existed on the Moon for millions or billions of years. The simple fact that the ice is there will help scientists construct models of impacts on the lunar surface and the effects of meteorite gardening, photodissociation, and solar wind sputtering on the Moon.

To scientists these finds are intriguing. However, deposits of ice on the Moon could have many practical aspects for future manned lunar exploration. There is no other source of water on the Moon, and shipping water to the moon for use by humans would be extremely expensive possibly $2,000 to $20,000 per kg.

The lunar water could also serve as a source of oxygen, another vital material not readily found on the Moon. Lunar water might also serve as a source of hydrogen which could be used as rocket fuel. Paul Spudis, one of the scientists who took part in the Clementine study, referred to the lunar ice deposits as possibly "the most valuable piece of real estate in the solar system." (1)

What We Know About the Moon

Exploration of the Moon continues to provide us with knowledge about our universe both past and present. In addition, it supports the development of new technologies and scientific discoveries. Although manned flights to the Moon have been discontinued, NASA continues to explore the lunar surface such as the Clementine and Lunar Prospector spacecraft which mapped the Moon extensively in l994.

Clementine Mission

The Clementine mission suggested that small, frozen pockets of water ice (remnants of water-rich comet impacts) may be embedded unmelted in the permanently shadowed regions of the lunar crust. Although the pockets are thought to be small, the overall amount of water may be quite significant--one billion cubic meters, or an amount the size of Lake Erie.

The Lunar Prospector

Unmanned and manned missions have changed our knowledge of the Moon. Lunar Prospector used its Neutron Spectrometer and Gamma Ray Spectrometer to determine the bulk elemental composition of the Moon as well as to identify potential lunar resources, including water ice (in the permanently shadowed poles.)

Primary Elements

The lunar crust is composed of a variety of primary elements including: uranium, thorium, potassium, oxygen, silicon, magnesium, iron, titanium, calcium, aluminum and hydrogen. When bombarded by cosmic rays, each element bounces back into space its own radiation, in the form of gamma rays.

Some elements, such as uranium, thorium and potassium, are radioactive and emit gamma rays on their own However, regardless of what causes them, gamma rays for each element are all different from one another---each produce a unique spectral "signature" detectable by an instrument called a spectrometer.

Lunar Crystal Magnetism Using data obtained from both its Magnetometer and Electron reflectometer instruments, Lunar Prospector will correlate magnetic anomalies with lunar surface geology. By mapping global locations, strengths and orientations of lunar crystal magnetic fields, scientists can learn more about the relationship between such magnetic fields and the surface selenology.

Magnetic measurements can also supply information about the size and electrical conductivity of the lunar core---evidence that will help scientists better understand the Moon's origins.

Crystal Structure

The crust ranges from 38 miles on the near side to 63 miles on the far side. Blanketed atop the Moon's crust is a dusty outer rock layer called regolith. Both the crust and regolith are unevenly distributed over the entire Moon. The regolith varies from 10 to 16 feet in the maria to 33 to 66 feet in the highlands.

Scientists think that such asymmetry of the lunar crust most likely accounts for the Moon's off-set center of mass. Crystal asymmetry may also explain difference in lunar terrain, such as the dominance of smooth rock (maria) and the near side of the Moon.

Lesson Plans And Activities

"Moon Maps"

LEVEL: Grades 4-6

Form teams of 2 or more students

OBJECTIVES:

l. To find specific craters and seas on the Moon
2. To observe or locate on maps various craters and note their similarities and differences
3. To locate various places astronauts landed on the Moon
4. To create a map of the Moon

MATERIALS:

Binoculars or a telescope
Moon map
Stand and hand-held magnifiers
Photocopies of the Moon

Observation form
Pencil and clipboard

l. Draw a large circle about 16-18 inches wide on poster board. This represents the Moon's surface. Students will place the cutouts of the seas and craters in their correct locations.

2. Draw from a model the Sea of Crises, Sea of Tranquillity, Sea of Serenity, Sea of Fertility, Sea of Nectar, Sea of Cold, Ocean of Storms, Sea of Rains, Sea of Moisture, Sea of Clouds, The "Known" Sea, Sea of Vapors, Bay of Billows. Use poster board and outline in bold-black felt pen.

3. Paste in correct locations.

4. Research areas of the Moon and report to class. Discuss the mountains, craters, lava-flooded basins, etc. that you read about.

5. Observe the Moon using binoculars or telescope, if possible. Visually impaired students can use clip-on a magnifier on their telescope or can team with a student who can verbalize observations.

"RECORDING THE PHASES OF THE MOON"

LEVEL: Grades 4 -6

OBJECTIVES:

1. To chart the phases of the Moon for a minimum of one month period
2. To discuss patterns observed in the phases observed

MATERIALS:

Binoculars (optional)
Poster board
Black paper
Glue, scissors, foil, ruler
Compass
Clip-on magnifier
Cardboard cutouts of Moon phases--first quarter, full moon, last quarter outlined in bold -lined black magic marker

REQUIREMENTS: A clear view of lunar phases for a four week period after a new Moon is needed

1. Draw a chart with seven rows across and five columns down. Label one for every day of the week. Number the boxes of the grid from 1 - 29.

2. Record the Moon's appearance in boxes beginning with box 1. Continue to chart phases of the Moon every night possible. Label the phases--first quarter, full moon, last quarter.

4. Select the correct cutout that corresponds to phase of the Moon. Glue appropriate cutout in blank. Leave box blank if observation is not made. Continue this task for several week. How long before the Moon looks the same as in Box 1?

HOW MUCH CAN YOU LIFT ON THE MOON

LEVEL: Grades 4-6

Note: The Moon's gravity is so weak that objects weigh only one-sixth their Earth weight when they are on the Moon.

EQUIPMENT:

Containers: (2 of each)

clear plastic milk containers
plastic bag with raisins
2 cup of sugar
Other foods from kitchen that can be easily divided into bags

l. Select 2 identical items

2. Empty the contents of one item into its own separate container, then put a sixth back into the original packaging

3. Pick up the unaltered food. Compare the sixth-full package to feel how light things are on the Moon. To find how much you could lift on the Moon, multiply the heaviest weigh you can lift by six.

"MAKING A MOON DIAL"

LEVEL: Grades 4 -6

MATERIALS:

- Poster board
- Compass
- Scissors
- Ruler
- Pen
- Glue
- Newspaper
- Pushpins
- Foam core

During the course of a month, the Moon can appear in different parts of the sky, during the day as well as the night. A moondial will help you find just where in the sky the Moon will be on any given night.

PROCEDURE:

1. Draw a circle about 8 inches wide on poster board. Cut out the circle and draw another circle inside it with a 6 inch diameter. This will be the dial.

2. Divide the circle into 20 equal segments. Number them 0 to 29 working counterclockwise. Mark the Moon's phases in Boxes 0, 7, 15, and 23

3. Construct a wedge-shaped base from foam core, with a right angle at the top and the angle beneath it equal to you latitude.

4. Place the dial in the center of the base. Secure it using a pushpin in the center.

5. Find the Moon's phase from a newspaper, and put a mark in the corresponding box. In daytime, position the base outside so that the low end points north. Turn the dial so that Box 0 points at the Sun. The Moon lies in the direction from the center of the dial to your mark.

Adaptations…for Visually Impaired and Blind Students

Science is an important but often challenging subject for blind and visually impaired students. The best situation is one in which all students have access to the same materials and participate in the same activities as their sighted peers. However, some students will need and benefit from adaptations to a program. For these students, modifications and hands-on projects will allow students to be active members of their school program.

To derive maximum benefit from the science, visually impaired students will be presented with a multisensory approach to learning about the sciences. A multisensory approach allows students to acquire information from other sources of sensory input to compensate for reduced vision. Students will have direct access to objects, materials, and models, in order to gain knowledge and integrate information into concepts. Such a diverse and active teaching method can open new avenues for expression and creativity and serve to motive students by helping to stimulate interest and realize potential.

VISUALLY IMPAIRED STUDENTS

Visually impaired and blind students have very individual needs. Their vision may fluctuated due to many factors or may be influenced by factors such as lighting, glare, fatigue, or health issues.

Teaching this population requires unique and individual strategies based on the students' needs, the project at hand, and the skills they possess (such as using computers with Braille or speech word processing programs, speed listening, etc.) that allow them to participate and gain understanding of the material.

There is an overwhelming amount of visual material used in teaching science. To complicate matters science courses often require the reading of charts, measurements, observation, and other tasks that are made more difficult without the benefit of sight. Also, blind and visually impaired students often have limited access to materials in a format that they can use effectively. Translations of books and other materials into Braille, large print or audio tapes are often difficult or impossible to obtain. They may include: textbooks, class notes, chalkboard lectures, videotapes, computers, journal articles, supplementary reading materials, and handouts.

CONCEPT DEVELOPMENT

Understanding science concepts depends on: observation, data collection, recording, and analysis. The challenge of science is not just learning the facts or content but it is the process. For the visually impaired to understand science the process must utilize direct sensory experience with a variety of hands-on activities. Students need to touch objects, materials, and organisms in order to observe size, shape, texture, patterns and change. They should not limit their experiences to reading from texts or lectures on science facts but instead must be encouraged to find things out for themselves by exploring, manipulating, investigating , and experiment.

The most effective science activities are those that include numerous tactile and auditory interactions, and extensive manipulation of equipment, materials, and organisms. Students need to explore concepts via tactile methods whenever possible and encouraged to relate to acquired skills and knowledge to her own sensory environment

MULTI-SENSORY APPROACH

Students with normal vision learn a great deal through incidental and planned observation of activities. For the visually handicapped, instruction in science should be based on a multisensory approach directed toward the acquisition of information from other sources of sensory input. This multisensory approach will help to compensate for the reduced visual functioning.

Understanding science depends on the ability of the students to make observations and to quantify those observations. Visually handicapped do not learn effectively from distance visual observations. Instead they must have direct access to objects, materials, organism, procedures, and operations. This multi-sensory approach which integrates input from auditory, tactile, and olfactory, as well as, visual sources allows students to gain knowledge and integrate information into concepts.

To derive maximum benefit from the science visually impaired students must be presented with a multisensory approach that is diverse and active to compensate for reduced vision. This approach can help to open new avenues for expression and creativity and serve to motive students by helping to stimulate interest and realize potential.

STRUCTURED ENVIRONMENTS

It is imperative to have a very structured and controlled work space. It is essential to label all materials, supplies, and equipment in regular or large print or Braille. Labels need to be prepared a print size that is appropriate for the visual acuity and perception of the individual. Some use standard size print while others benefit from enlarged print. Blind students may be Braille or audio users or use a computer with adaptations to translate the written text to speech and produce a Braille translator with a Braille embosser.

Familiarize the student with the classroom, laboratory, equipment supplies, materials, field sites by allowing the student to explore these areas factually. A verbal description is also helpful.

Science lessons should be taught under uniform, diffuse lighting, with no glare, no shadows, and no strong back lighting. Contrast between objects and backgrounds should be bright rather than being pastel shades.

Each student should be encouraged to be involved in every step of lesson. It is important to that the visually impaired student to play an active not passive role in the team. For instance, they should not merely act as the recorder in experiments with sighted partners but should be encouraged to take part in each part of the activity.

TEACHER OF THE VISUALLY IMPAIRED / BLIND

The teacher of visually impaired serves as consultant to the science teacher and helps to select appropriate methods and materials and deal with instructional problems related to the teaching of specific lessons and concepts.

The teacher of the visually impaired should assist the science teacher by explaining the types of objects and actions students are able to see and under what conditions. This vision specialist should provide specific examples relative to the individual, rather than merely interpret the clinical information about the degree of vision. In addition, other sensory losses should be noted such as reduced tactile sense in diabetic children. Teachers should be sensitive to each student's cognitive learning style and provide science experiences that match that style.

MATERIALS

Real objects, organisms, and materials for classroom and experiments need to be provided and should include sturdy objects and organisms of appropriate size for tactile examination.

Descriptions of visual activities and an alternative to chalkboard work, printed diagrams, photographs will allow the visually impaired to have the information they need to be a part of the class. For the low vision student clear, high contrast printed materials are necessary.

It may be necessary to acquire specialized tools, data recording materials and other materials such as Braille rulers, thermometers, and talking calculators, and scales. In addition, teacher-made materials such as organizational containers include common objects such as muffin tins or egg cartons to help structure the activity for the student. Often equipment and materials can be easily modified to assist the student in their work. For example, a physical stop fixed to a syringe so the plunger can be pulled out at preset measurements or tactile notches cut in the edges of the plunger of a syringe to determine a variety of volumes.

ADAPTATIONS

Some of the strategies suggested will assist some but not all visually impaired students. The student's background and training and the degree of the visual impairment are all factors in whether these strategies and suggestions will be helpful to any one individual with a visual impairment.

Students with vision impairments will need assistance in areas such as accessing instructional materials, taking notes, and tests. A means for the acquisition and recording of data must be provided in the mode most familiar and appropriate to the student. It is necessary to provide accessible description for pictures, graphics, or displays. Verbal descriptions of diagrams and photographs, demonstrations and visual observations of experimental outcomes are also required. Low vision students should be encouraged to incorporate the use of their vision whenever possible.

There is a wide selection of magnifying devices available including stand mounted and hand held models. These may be helpful of some students to assist them in reading or working with items or equipment that need to be observed

GUIDELINES FOR MODIFICATIONS

There are many adaptations in equipment and teaching procedures that are helpful in teaching science to blind and visually impaired. In addition, computers are playing an important role in enabling visually handicapped to study and work in science. The following guide may be helpful.

1. Spell new or technical words
2. Use enlarged directions or a 3D models
3. An overhead projector or closed circuit television can be used to show step-by-step instructions or to enlarge a text or manual. It is helpful to mask all the items except the one you are stressing at the moment
4. Provide Braille labels for colored objects used for identification in a lesson or experiment
5. Describe visual occurrences, visual media and directions of pertinent aspects that involve sight in detail
6. Use a sighted narrator or descriptive video to describe aspects of videos or laser disks
7. All pertinent visual occurrences or chalkboard writing should be described in detail even when

a note taker is available
8. Lessons, class handouts or directions should be provided in Braille, enlarged print, or on tape
9. Tactile 3-D models, raised line drawings or thermoforms should be made available to supplement drawings or graphic
10. Use actual objects for three dimensional representations whenever possible
11. Raised line drawings can be used for temporary tactile presentations
12. Overhead projects, chalkboard talks, graphs or slides should not be avoided but must include more detailed in the -oral descriptions, supplemented with themoforms where appropriate
13. The student should be allowed to use a tape recorder to record lectures and class presentations
14. Handouts and assignments must be available in appropriate form: regular print, large print, Braille, cassette this will depend on students optimal mode of communication and training
15. A monocular may be useful for long range observations of chalkboard or demonstrations
16. Call student by name to gain attention
17. Use descriptive words. Provide specific directions. Avoid vague terms.
18. Describe pertinent visual occurrences of the learning activities in detail
19. Changes in assignments and meeting sites should be given verbally.
20.It is helpful to offer to read information in some situations
21. At times an auditory signal may be helpful where a visual signal normally is used
22. Use stable and non breakable materials
23.Containers and materials should be labeled in Braille and large print.
24.Use high contrast between material and work surfaces whenever possible
25. Be certain written materials are accessible to student including textbooks, journal articles, teacher handouts
26. Make use of Braille, audio tapes, large print and sighted readers

LABORATORY MODIFICATIONS

Laboratory exercises can be accessible to students if equipment is available that allows them to access, interpret and understand the results of laboratory exercise. Such devices include audible readout voltmeters, calculators, talking thermometers, talking compass and scales, and magnifiers.

Additions suggestions for laboratory exercises include:

1. Teaming the student with a sighted student or providing a tutor to describe the activities and outcomes as they are observed.
2. A hot plate can be used instead of a Bunsen burner
3. A micro projector can be used to help a visually impaired student examine images from a microscope
4. Allow more time for laboratory activities
5. Describe and factually and spatially familiarize student with lab and equipment
6. Location of materials, supplies, equipment and how it is used. They should be kept in the places and a Braille or large print label should
be used. Braille or large print tags can be used on containers
7. Overhead projector or opaque projector is helpful for some to show step-by-step instructions. A low vision closed circuit television can be used to magnify images up to 720 times.
8. Taking a trial run on the equipment will help the student to become familiar
9. Use tag shapes for showing relationships (such as distance comparison) buttons, or other markers on a "layout" board
10. Portable communication board can be used to provide auditory scanning of laboratory materials such as: pictographic symbols, letters or words. Obtain laboratory equipment that have adaptive outputs such as: a large screen, print materials, various audio output devices, Braille and large print translations of books prior to enrollment
11. Allow more time for laboratory activities

FIELD EXPERIENCE MODIFICATIONS

1. Provide handouts, safety information and assignments available in appropriate form including regular or large print, Braille, audio cassette.
2. Provide a detailed description and narration of objects seen in science centers, museums and field activities
3. Ask a classmate to act as a sighted guide
4. A laser cane or Mowatt sensor are electronic travel aid that can be helpful in assisting the student in unfamiliar surroundings
5. Provide a tape recorder for use by the student.

RESEARCH MODIFICATIONS

1. Tape record, computer, various Braille devices to assist in reading and note- taking
2. Use of appropriate lab and field strategies according to the nature of the research
3. Make arrangements for tactile examination if allowed by the museum or research center

TESTING ADAPTATIONS

1. Allow additional time for testing.
2. Testing should be present in a form that will be unbiased for visually impaired
3. The student may be able to help you understand which method is most accessible
4. Talking and large print display calculators should be available.
5. Record test questions on tape and allow students to record their answers on tape
6. The activity script, directions or readings can be taped
7. 3-D tactile models can be used
8. Modifications may be made or specialized equipment such as talking thermometers, talking scales, etc.

READING

There are a number of devices that can be used to assist vision impaired students when reading including closed circuit televisions which enlarge pages of written material. They can be very portable and provide the student with instant enlargement of pages.

Tutors or volunteer readers or writers can assist student with tests, materials, research by reading materials for students.

The teacher of the visually impaired should arrange with Talking Book Service or Recording for the Blind for audio books to be produced of textbooks or other reading materials.

THE SCIENCE ACCESS PROJECT

The Science Access Project at the University of Oregon was developed to ensure full accessibility of electronic information by individuals with visual difficulties. This project promotes the development of technologies that will allow full access of electronic information to individuals with print disabilities. Their philosophy is that information should be created and transmitted in a form that is as display-independent as possible with the user having maximum freedom over how information is displayed. This, it is believed, will lead to maximum usability by everybody and will assure equal access. Ideally information should be made accessible by controlling the display, not the information itself.

Science Access Project concentrates on accessibility of non-textual information including:

1. new and improved paradigms for tactile and audio-/visual information display
2. hardware for tactile information display
3. software that utilizes display-independent information and multi-modal access

TACTILE INFORMATION DISPLAY

Science Access Project (SAP) actively promotes reforms in Braille and development of DotsPlus paradigm used to represent more general text and graphics. Braille is a tactile method of representing words by dot patterns. Fewer than 15% of American who are legally blind and read Braille. Even few of those readers can read the special Braille codes needed to represent math, science, and computer programs. Therefore there is a movement to develop a more useful method of Braille. This new unified Braille code would allow readers to represent math and science in a more simple fashion.

DOTSPLUS

Dotsplus is a tactile font set developed by SAP. Dotsplus permits straightforward tactile hard-copy representation with the same format used in print. Signs such as plus, equals, times, parentheses, fraction bar, etc. are represented by tactile images with the same shape as the print symbol. Although it is not easy to distinguish the shapes of letters and numbers factually. SAP developed the TIGER (Tactile Graphics Embosser) which is a high-resolution embosser that can print DotsPlus. In addition, to is a major improvement in making graphics accessible.

AUDIO/VISUAL DISPLAYS

A wide range of software applications that utile audio display is being developed by SAP:

1. The TRIANGLE program is able to display x-y graphics and bar-charts through tone displays. To display formatted text, tables and math equations a variety of speech enhancements and non-speech audio are used in TRIANGLE.
2. The Audio System for Technical Reading (AsTeR) is a reader program that presents scientific expressions compactly in speech and other audio. Audio formatting use a higher pitch for superscripts and lower pitch for subscripts. They also group symbols by changing tone or rate and by using strategic pauses. Different words may also be used depending on context
3. EmacSpeak is a self-voicing system that has expanded the accessibility of blind users to the UNIX operating systems

TACTILE HARDWARE

Methods and hardware for making tactile graphics materials for blind users including:

1. Swell paper is the only practical methods for making tactile graphic materials from computer applications. To do this a black image is transferred to this special paper. It is then passed through an infrared heater that makes the black areas swell. The images however are soft and not very pleasant to read. The process is also expensive at a cost of dollar plus per sheet to produce. Also the process is cumbersome.
2. A new embossing technology has been developed and patented by Oregon State University that produces a high-resolution tactile graphics (20 dots per inch) to be embossed on standard Braille paper and plastic media. It is able to produce smooth lines in vertical and horizontal directions. The company that purchased the license for this technique is working on a commercial embosser.

3. In 1997 a prototype personal embosser called TIGER was exhibited at the March of 1997 at the International Conference on Technology and Persons with Disabilities, in Los Angeles. TIGER automatically converts fonts to a user-selectable computer braille representation using Windows 95 and a printer driver.

TRIANGLE

The Science Access Project wrote a computer program that permits blind people to read, write, and calculate math and science problems. Written in DOS it requires a DOS screen reader and includes a math/science word processor, graphing calculator, a viewer for y versus x plots, a table viewer. It also Touch-and-Tell, a computer-assisted reading program of tactile figures that uses an external digitizing pad.

Triangle allows a keyboard or any specialized device that emulate a keyboard to be used to provide input. The output is transmitted in several ways:

1. Visually with text on the DOS screen
2. Audibly with the assistance of a screen-reading program, external voice synthesizer and PC speaker
3. Factually with use of a braille screen access program and external refreshable braille display

Triangle also can provide the user with visual, audible, and tactile output simultaneously.

GRAPHIC ACCESS

Often graphical information is available only in printed hard copy or as electronic bit-mapped images and must be make accessible to blind or visually impaired individual. Several programs including the Objective and Boxer programs support access to graphical information. They are designed to simplify the process for the sighted transcribed making tactile copes and the electronic label maps necessary for blind users to read complex figures.

These programs are available free of charge through SAP. They require use of the Nomad tablet (American Printing House for Blind), the TRIANGLE Touch and Tell view, and audio/tactile viewing programs. They are designed to assist sighted people in making tactile graphic materials for blind users.

OBJECTIVE

This is a programs that implies editing bit-mapping graphics. It prints using a braille graphics printer. Users are able to make an electronic label file for viewing with the Triangle. Objectif is a Windows program that intrinsically requires some sight for its use.

Boxer was designed to make trees and flow charts that can be printed on a standard braille text printer. Boxer can be used by a blind person.

VRML VIEWER

It is important to assure that all electronic informational graphic is accessible. The VRML viewer is used in many world wide web applications and has been demonstrated to be fully accessible to graphics. For instance, the periodic table of chemical elements can be made accessible using a standard VRML browser that speaks object labels when you click either on-screen or on a tactile copy sitting on the external touch pad.

SCREEN

UNIX is an operating system originally used on mainframe computers. It now is also used on many stand-alone work stations in companies and universities. UNIX was accessible only through DOS machines used as terminals. This lack of direct access prevented blind and visually impaired users from working with this system. Now, however, SAP has developed a direct braille access to UNIX text applications.

Screen is a full-screen window manager. It multiplexes a physical terminal between several processes such as interactive shells. Braille additions have been added to Screen to allow the user to view these directly with the display without having to log in through a DOS machine.

TUTORS

Assistance from a paid tutor or volunteer can provide the following services:

l. Reading texts, lecture notes and other documents
2. Production of braille and tactile educational materials
3. Typing and proofreading of term papers and assignments
4. Assisting with laboratory work

Annotated Bibliography

Teacher Resources

Koppeschaar, Carl, Moon Handbook, A 21st Century Travel Guide, Moon Publications Inc., 1995, Chico Calif (This handbook is a history of the moon with information on mythology, tours of the near side of the Moon including craters, seas, mountains, and valleys) NASA NEWS Release: H98-38 "Lunar Prospector Finds Evidence of Ice at Moon's Poles," (March 5, 1998) (This news release provides the latest information from NASA on the evidence of ice on the moon's poles.) Spudis, Paul D., The Once and Future Moon, Smithsonian Institution, Washington, D.C., l996 (A well-organized primer of current knowledge and future prospects it presents an excellent summary of the moon's origin as well as the Apollo missions) "Lunar Prospector Finds Evidence of Ice at Moon's Poles" NASA NEWS Release

1) Stability of polar frosts in spherical bowl-shaped craters on the Moon, Mercury, and Mars, Ingersoll et al., Icarus, v. 100, p. 40, 1992

2) The behavior of volatiles on the lunar surface, Watson et al., Journal of Geophysical Research, v. 66, p. 3033, 1961

3) Ice in the lunar polar regions, Arnold, Journal of Geophysical Research, v. 84, p. 5659, 1979

4) The Clementine bistatic radar experiment, Nozette et al., Science, v. 274, p. 1495, 1996

NASA Press Release (5 March 1998) Dr. David R. Williams, Williamnssdc.gsfc.nasa.gov, (301) 286-1258

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Last Updated: 19 March 1998, DRW

Annotated Bibliography

Children Resources

Henbest, Nigel and Couper, Heather, How The Universe Works: 100 Ways Parents and Kids Can Share The Secrets of the Universe, The Reader’s Digest Association, Inc., Pleasantville, New Yor ek, l994 This collection of science projects is an excellent resource for class projects and parent / child projects.

Jones, Brian and Gutelle, Andrew, Facts America Our Solar System ,SMITHMARK Publishers Inc, New York, NY, 1992.

This is an informative book for individuals interested in exploring the Sun, Moon, and stars through color photographs, charts, and illustrations with excellent summaries Pascuzzi, Edward and Harrington, Phillip, Astronomy For All Ages: Discovering The Universe Through Activities for Children and Adults, The Globe Pequot

Press, Old Saybrook, Ct., l994

This book provides information on scientific investigations that can be conducted in the home or school. Van Cleave, Janice, Astronomy For Every Kid: 101 Easy Experiments That Really Workk, John Wiley and Sons, Inc. New York, l991

(This book provides useful and interesting C projects for students interested in learning about astronomy.)
