



McREL's Adapted Curriculum Enhancement Program (ACE) Visualizing Science Guidelines for Designing Tactile Graphics

Introduction

One of the goals of the *Feel the Impact: Empowering Visually-Impaired Students Through NASA Adaptive Curriculum Enhancement (ACE) IDEAS* grant was to develop comprehensive guidelines for use by NASA mission Education and Public Outreach (E/PO) providers and the general public when adapting graphics and images for visually impaired students.

The ACE Visualizing Science Guidelines for Designing Tactile Graphics were compiled as developers received feedback from both students with many types of visual impairment and educators at the Colorado School for the Deaf and Blind (CSDB) during pilot test sessions. Classroom teachers involved in our national field tests indicated that ACE materials helped students "visualize" abstract science concepts.

The Guidelines

These guidelines include recommendations for selecting images and aspects of images to adapt (Selection Criteria), suggestions for consistently formatting graphics and tactile cards (General Format Criteria), methods used to design tactile graphics (Design Criteria), and advice on writing verbal descriptions to accompany the graphics (Written Description Criteria). A brief description of each criterion is presented below followed by examples developed through McREL's ACE program.

Selection Criteria. Selection criteria are the decisions that are made in both selecting the type of graphic that is to be adapted as well as considerations about how to adapt the graphic at the onset. Science research and educational materials often depend upon photographs, illustrations, and graphical representations to convey a deeper understanding of abstract concepts to the reader. Although visually-impaired readers can access the textual information using Braille translation, large-font hard copy or screen-reader technology, any data or detail contained in drawings or photographs that are not described in the text cannot be accessed by many visually-impaired students.

General Format Criteria. The general format criteria provide guidance for setting up each tactile card. They should be used consistently, so that the visually impaired can become familiar with a standard convention for interacting with a tactile card. Over the seven-year learning period in which these guidelines were developed, the designers of the ACE materials learned early on that there are no "one size fits all" guidelines when working with visually-impaired students. There are, however, some general principles that can apply in most circumstances.

Design Criteria. The design criteria provide guidance for adapting imagery and graphics into line drawings that can be embossed using a Swell-Touch or other similar system. One of the most important lessons the developers learned as they created tactile graphics for visually-impaired students was to make the design simple and consistent. Just because a graphic "looks" good doesn't necessarily mean that it "feels" good.



Written Description Criteria. Written descriptions for each tactile graphic are essential to ensure that the student is able to observe the information conveyed in the graphic. Written descriptions should accompany each tactile graphic card. The directions for observing the tactile graphics and the description of the components of the graphic require a different perspective and, in some cases, a different vocabulary than the usual scientific writing. However, the textual description of the graphic is critical to the student's understanding of the deeper science concept being conveyed by the graphic.

Selection Criteria

Selection criteria are the decisions that are made in both selecting the type of graphic that is to be adapted as well as considerations about how to adapt the graphic at the onset.

1. Decide what purpose or basic component(s) of the science concept or process you want to convey for your students, (e.g. energy transfer, physical structure, spatial relationships).
2. Consider what previous experience or background the target audience has had with this concept.
3. Decide how you can convey this concept or process using either a 2-dimensional graphic or a familiar object as a model. Whereas visual learners can look at the whole picture and break it down into component parts, visually-impaired students must “look through their fingertips” at component parts and construct a visual image of the “whole”.

a) What components CAN you convey tactilely? Will you need more than one tactile or object to describe the content or process?

b) What limitations will the tactile graphic or familiar object model have? What will you need to do in the observation description to overcome these limitations?

c) As you adapt an illustration or photographic image remember, “Less is better”. Eliminate any details that will be confusing to the touch. Include only the *necessary* lines and textured areas.

4. Think carefully about the type of visual impairment of each student and how you might accommodate for a lack of visual background or perception as you design materials to help them form “mental images” of the selected science concept or process.

Examples and Applications of the ACE Selection Criteria include:

1. See Appendix A, pages 6-7 for a method of incorporating *perspective* into the “Spongy Universe” module.
2. In “Tracing Origins” we found that many visually-impaired students had never “observed” an unbaked pizza.
3. For “Cratering in the Solar System” we designed landscape tactile images *without horizon lines* for blind students who had not experienced the horizon. See TG 9b-9i, http://www.ace-education.org/graphics_guide/index.asp.



General Format Criteria

The following general format criteria provide guidance for setting up each tactile card. They should be used consistently, so that the visually impaired can become familiar with a standard convention for interacting with a tactile card.

1. Always put tactile number in the same location. Number graphics in one lesson or module consecutively. You may wish to include a letter symbol in the label.
2. Include short captions in same location so student can use them to recall what they are observing. Allow adequate space for 18-pt bold Low-vision text and regular-size Braille numbers and captions.
3. Include a starting point. (We found that an open circle proved to be easier to locate than a closed large dot.)
4. Position the starting point so that the observation directions can move out, down, or the right of the starting point without backtracking.
5. Do not use border or framing lines. These are confusing for students when they are told to follow a line and they follow a framing line.

Examples and Applications of the ACE General Format Criteria include:

1. All ACE graphics are numbered in the upper left corner. See *Feel the Impact Comet Structure TG3* on Appendix A, page 8.
2. The graphics for the Ejecta and Plume activity were labeled EP1- EP8 to differentiate them from graphics that were part of the general *Feel the Impact* materials. Appendix A, page 10.

Design Criteria

The following design criteria provide guidance for adapting imagery and graphics into line drawings that can be embossed using a Swell-Touch or other similar system.

1. Decide what size graphic is most appropriate. Either too large or too small a scale can make tactile perception difficult and may be confusing for low-vision students.
 - a) Sometimes the property of scale is not so important as location of parts with respect to each other.
 - b) There are times when it is best to use a series of graphics to convey a complete process. If it is necessary to change the size of scale of a particular object from one graphic to the next, plan carefully how you will clarify this for your student.
2. Eliminate all possible detracting lines or details when they are not essential to understanding the concept.
3. Replace detailed objects with regular shapes and labels if possible. Labeled rectangles, circles, and ovals can be used to

Examples and Applications of the ACE Design Criteria

In the Cratering in the Solar System section of *Feel the Impact* depicting the process of cratering required nine different tactile cards, # with descriptions explaining how energy was transferred during an impact. Different sized arrows were used to indicate the amount of energy being transferred in each graphic. See TG 9b-9i, http://www.ace-education.org/graphics_guide/index.asp



represent irregular objects unless their irregular shape is critical to understanding their function. In that case, decide if the shape can be simplified so that it can be easily observed tactilely without loss of concept.

4. Remember, just because it LOOKS good doesn't mean it FEELS good.
 - a) If you are modeling a smooth section, use no fill. Any kind of fill, even a solid color, which you perceive with your eyes as being smooth, will not feel "smooth" to the touch.
 - b) Be very selective in "fill" textures when areas are adjacent. The different textures may appear to your eyes as very different, but may prove difficult to "feel" as different.
 - c) Small texture patterns or large patterns with little space between them are difficult to feel.

[Note: To make your adapted drawings into Swell-Touch tactile graphics cards, follow the instructions on the ACE Web site at www.ace-education.org/media/tact_graph.asp.]

Written Description Criteria

Written descriptions for each tactile graphic are essential to ensure that the student is able to observe the information conveyed in the graphic. Written descriptions should accompany each tactile graphic card.

1. Include some wording to describe to the student what is being shown overall in the graphic. This description should include some orientation as to whether this graphic is attempting show a three-dimension object in 2-D, whether it is a diagram that represents the flow of energy from one location to another, or is showing relative spatial locations of one part of a system to other parts in the system.
2. Give directions to find starting point
3. Give specific directions for moving away from the starting point. Describe the first "object" they should "look" for, whether it is a line, a textured or a smooth area. Should they observe that object now or move through it and observe it later?
4. Use the term "track" rather than "trace" when referring to following a given line with your finger. Visually-impaired students interpret the word "trace" to mean that they should literally trace an object onto another sheet of paper.
5. Use a font color and size that is most useful for the individual student.
 - a. Low Vision: Provide written descriptions and texts in 18 point, Arial, bold for most low-vision students. Some may prefer **Bold Black** on colored background or **Bold White** on black background
 - b. Blind using Screen Readers: Provide written descriptions and texts in 14 point Arial.
6. When developing texts for screen readers, do not include headers, footers or graphics in the text as they are confusing for many screen readers.

Examples and Applications
of the ACE Written
Description Criteria
See the observation text,
"What kind of structure do
comets have?" that
accompanies the Comet
Structure tactile graphic on
page 9 of Appendix A.



Appendix A: Examples and Applications of the ACE Visualizing Science Guidelines for Designing Tactile Graphics

Selection Criteria Example from *Evolving Universe*

The materials in the following pages illustrate how the ACE Visualizing Science Guidelines can serve as the basis for incorporating *National Science Education Standards* (NSES) Content Standards for Science as Inquiry and Earth/Space Science into the design of tactile graphics and use of common items as models that enable visually-impaired students to form “mental images” of abstract science concepts.

During the development an education module on Cosmogony, a component of the E/PO for NASA’s Discovery Mission Genesis , James Trefil’s description of our universe as “The Spongy Universe” inspired the use household sponges as models for cosmic structures. Cosmic structures have been described as “pearls in a necklace”, cross-linked filament-, and lace-like as well as both *homogeneous* and *isotropic*. These descriptions also served as an opportunity to focus on both NSES Earth/Space Science Content and Science as Inquiry Standards.

We began the visualization process by asking students to *describe* real sponges. Then we introduced the lace samples, pearls, and cross-linked jewelry to observe whether and to relate the characteristics of those objects to the structure of the sponge.



Standards Addressed

Concept: Cosmic structures

NSES 9-12 Earth and Space Science
The Origin and Evolution of the Universe
Early in the history of the universe, matter clumped together by gravitational attraction to form most of the visible mass in the universe.

NSES 5-8 Science As Inquiry Skills:

Students should:

- *develop systematic observation skills;*
- *base their explanation on what they observed; and,*
- *be able to differentiate explanation from description.*

After visually-impaired students *observed* the solid network and holes in household sponges, they made *inferences* about how the holes in the sponge were formed.

This inquiry skill was then applied to the voids in cosmic structures. Using the sponge as a model of cosmic structures, students were asked whether those same kinds of inferences could explain how the cosmic structures were formed?



We then turned to tactile graphics to help students understand the concepts of homogeneity and isotropism as they apply to cosmic structures. The text in brackets [] below reflects our consideration of the Selection Criteria Guidelines questions as we designed the “sponge” tactile graphics.

Selection Criteria

The following selection decisions apply both to analyzing an illustration or diagram from a textbook or to designing an original tactile graphic.

1. Decide what purpose or basic component(s) of the science concept or process you want to convey for your students, *i.e.* energy transfer, physical structure, spatial relationships, etc. Consider what previous experience or background your students have had with this concept.

[We wanted to show how the holes in the sponge tend to disappear, thereby making a filamentous structure with holes appear more homogeneous and isotropic, as the distance between the observer and the sponge increases.

Visually-impaired students have limited experience (if any) with the apparent decrease in size of an object as the distance between the object and observer decreases. This apparent decrease in size also decreases the ability to observe detail.]

2. Remembering that “less is better”, decide how you can convey this concept or process either by using a 2-dimensional graphic or a familiar object as a model.

[We considered either raising the solid structure or raising the holes as we used the sponge as a model for the 2-dimensional graphic. We found that raising the structure produced a better model and made the homogeneity easier for students to “feel” as the size of the sponge (and its detail) became smaller.]

a) What components CAN you convey tactilely? Will you need more than one tactile or object to describe the content or process?

[Yes. At first we thought that we would need at least five graphics, but found that three was sufficient.]

b) What limitations will the tactile graphic or familiar object model have? What will you need to do in the observation description to overcome these limitations?

[We will have the students observe tactilely the surface of the real sponges and then the 2-D tactile graphic so that they can observe the differences. There is much less detail of the sponge structure in the tactile graphic.]

c) As you adapt an illustration or photographic image, eliminate any details that will be \ are confusing to the touch. Include only the *necessary* lines and textured areas.

[We made the solid structure “solid” without an strands or layers like those of the real sponge.]

3. Think carefully about the age of your students and what lack of visual background or perception you must provide for and/or accommodate as you design materials to help them form “mental images” of the selected science concept or process.

[The visual concept of *perspective* had to be introduced.

We provided wording in the description to help students orient themselves to the decreasing size of the tactile graphics. Starting with the “real-size” model, we had them place it side-by-side with the 2-D graphic. Then we moved to the farthest side of the classroom and took the real sponge with us. We told them that the real sponge had not changed size, but that it appeared smaller (like the mid-sized tactile graphic) to people who could see. Partially sighted students confirmed that. Could the holes in the graphic still be detected by feel? Yes.

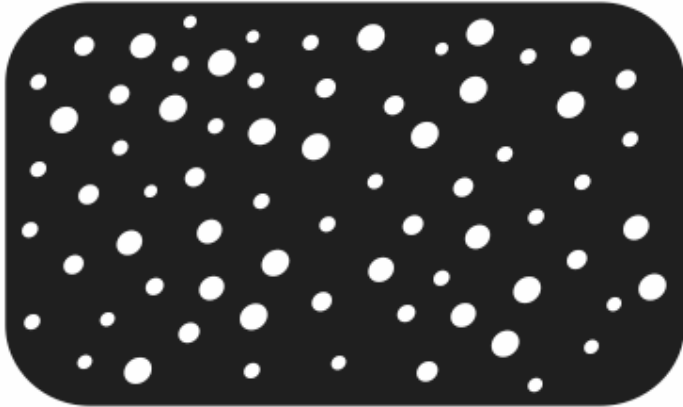
Then we asked partially sighted students how large the sponge would look if I took it to the parking lot that students were familiar with finding when they boarded the school bus. They agreed that the sponge would look about the size of the smallest of the tactile graphics. Can the details (holes) in that graphic still be felt? No.

From there we could go on to explain that the cosmic structures were many times as large as the sponge but that they were also at many times farther distant than the parking lot.

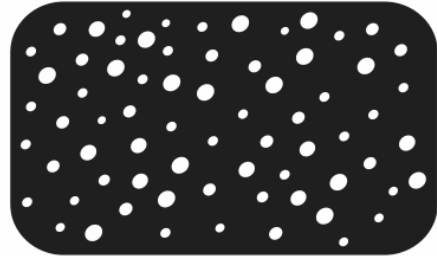
Three sizes of tactile models of a sponge surface were used to help students “visualize” that, at great distances, cosmic structures appear to be both *homogeneous* and *isotropic*. The concept of *perspective* was modeled by different sized tactile graphics of a sponge surface. As students observed that, as the tactile graphics grew smaller with an increase in distance between the object



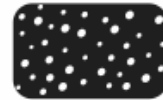
and the observer, the more difficult it is to feel the holes. The surface of the sponge feels more homogenous as it gets further away.



In full size tactile graphic of sponge, students can observe the holes in the surface.



The sponge appears to be this size when it is across the room.



The sponge appears to be this size when it is in the parking lot.

Design Criteria, General Formatting Criteria, and Written Description Criteria Example from *Feel the Impact*

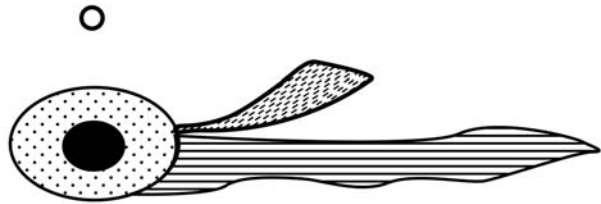
Developing the *Feel the Impact* materials based on the NASA Discovery mission Deep Impact provided new challenges in that there was new information and surprising results from the mission being posted during the development of the adapted materials. We decided to incorporate analysis of some of these data into a module in which students study the structure of comets and cratering.

<p style="text-align: center;">Standards Addressed Concept: What are comets?</p> <p>NSES 5-8 Earth and Space Science Earth in the Solar System <i>The earth is the third planet from the sun in a system that includes smaller objects, such as asteroids and comets</i></p> <p>NSES 5-8 Science as Inquiry <i>Students should be able to access, gather, store, retrieve and organize data.</i></p> <p>NSES 9-10 Science as Inquiry</p> <ul style="list-style-type: none">• <i>A variety of technologies, such as hand tools, measuring instruments, and calculators, should be an integral component of scientific investigations. The use of computers for the collection, analysis and display of data is also a part of this standard.</i>• <i>Mathematics plays an essential role in all aspects of an inquiry.</i>
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Braille symbol: 3.

The tactile graphic to the right shows the nucleus and the coma of the comet. The solid dust particles and the gases from the nucleus and coma fan out to form a straight dust tail and a curved gas tail. The following Design Criteria guidelines were considered as the tactile graphic template was drawn.



Design Criteria

1. Do not use border or framing lines.
2. Decide what size graphic is most appropriate. Sometimes the property of scale is not so important as location of parts with respect to each other.
[In this case, the size of the comet’s head—the nucleus and the coma—is not shown on the same scale as the comet’s tails. Had the overall size of the graphic remained the same, the size of the comet’s head would have been too small to detect the nucleus from the coma. We included the sizes of comet heads and tails in the written description to give students some idea of their relative sizes. (See underlined portions of description below.)]
5. Remember, just because it LOOKS good doesn’t mean it FEELS good.
 - b) Be very selective in “fill” textures when areas are adjacent. The different textures may appear to your eyes as very different, but may prove difficult to “feel” as different.
 - c) Small texture patterns or large patterns with little space between them are difficult to feel.

Note how the graphic incorporates the General Format guidelines below.

General Format Criteria

1. Always put tactile number in the same location
[The Braille symbol for the number 3 is just to the left of the text number.]
2. Include short captions in same location so student can use them to recall what they are observing.
[The Braille caption is not shown in this version, but is included in the full-sized template found in the web-site.]
3. Include a starting point.
[We found that an open circle proved to be easier to locate than a closed large dot for both low-vision and non-vision students].
4. Position the starting point so that the observation directions can move out, down, or the right of the starting point without backtracking.
[Note the written directions not only instruct students to move their fingers down from the open circle but also how to make sure that they are moving straight down.]

The written description that students use to observe the graphic is just as important as the graphic itself. The instructions for use of this tactile graphic were embedded in the student text below.

Written Description Criteria

1. Include some wording to describe to the student what is being shown overall in the graphic.
[This is *shown in italics* in the description.]
2. Give directions to find starting point.
[The text in **bold type illustrates** items 2 and 3.]
3. Give specific directions for moving away from the starting point. Describe the first “object” they should “look” for, whether it is a line, a textured or a smooth area. Should they observe that object now or move through it and observe it later?



The name of this student text is
“What kind of structure do comets have?”

Comets have three parts: the nucleus, the coma and the tails. Use Tactile Card three to follow the description of these comet parts.

This graphic represents a slice through the comet, like a slice of an apple cut through its equator. Just like a whole apple extends in all directions, every part of the comet that you feel is also coming out at you and going back into the paper.

Find the card number, either in print or in Braille, in the upper left corner. From the card number move your left pointer finger to the right until you find the open circle starting point

Place another finger of your left hand on the edge of the card to help your pointer finger travel straight down from the starting dot.

Move your fingers down until your pointer finger moves through a textured area and finds the large filled oval. This oval represents the nucleus of the comet.

This solid center structure represents the nucleus of the comet. It is made of ices of volatile compounds and rocky debris. It has a dark surface of different colors.

The nuclei of comets range in size from less than one kilometer in diameter to as large as three hundred kilometers.

On its longest axis, Comet Tempel One measures almost seven kilometers. This is about three-fourths of a mile.

As a comet approaches the sun, heat from the sun warms the surface of the nucleus. The ices sublime; that is, they change from a solid to a gas without going through the liquid phase.

As the gas leaves the comet's surface, it carries dust along with it. This “cloud” moves out in all directions, forming a coma, an atmosphere around the nucleus.

Move your finger out in any direction from the solid oval to feel the textured region inside the boundary line that represents the coma.

Can you feel that the nucleus is embedded in the coma? Together the nucleus and the coma form the head of a comet.

The solid dust particles and the gases from the nucleus and coma fan out to form a straight dust tail and a curved gas tail.

Move your finger to the right of the coma to feel two regions filled with different textures.

The top curved region represents the gas tail. This tail always points away from the sun. So sometimes this tail can be in front of the comet as the comet heads away from the sun along its orbit.

The bottom region represents the straight dust tail. The dust tail becomes visible when the sunlight reflects off the dust in both the coma and the tail. The dust tail often appears yellow in color.

Energy from the sun ionizes some of the particles in the straight gas tail. These glowing ions emit a blue light as they move away from the energy source.

A third tail made up of atoms of sodium can also be seen in some comets.

Comet tails can vary in length from very short ones to those that extend millions of miles through space.

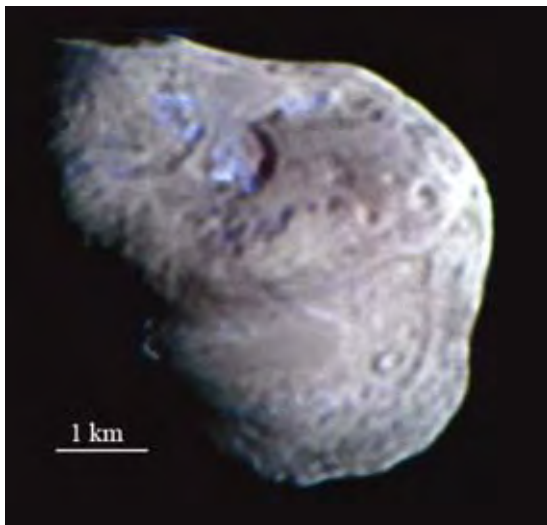
Comets don't have continents or molten rock. But there is evidence of flow of some kind on Tempel One as well as multiple layers that may have piled up over time.

The coma is the only atmosphere, so there is no water driven weathering as on Earth.



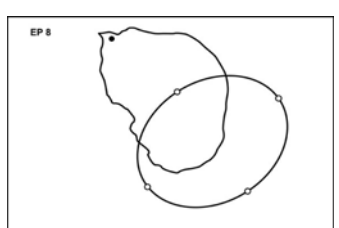
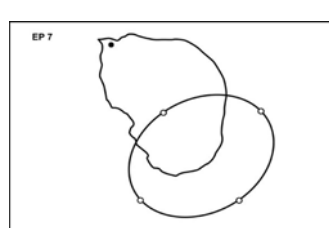
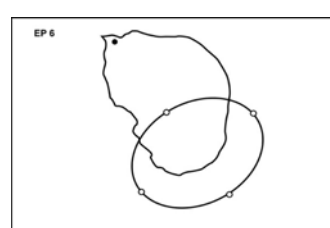
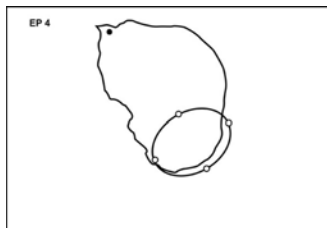
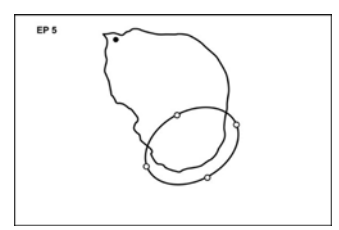
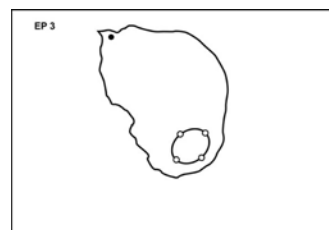
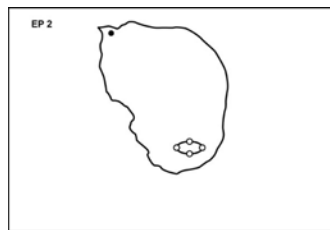
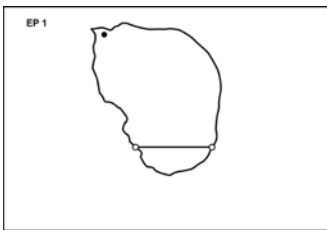
Using a 3-D Model Example from *Feel the Impact*

This image of Comet Tempel 1's nucleus surface features, found at: <http://deepimpact.umd.edu/gallery/images-results.html> was used to create 2- dimensional tactile graphics and 3-dimensional models (see images on the next page) of the comet's surface features for visually-impaired students' observation and analysis.



Ejecta and Plume Graphics EP1-EP8

This series of tactile graphics were adapted from photographs of the ejecta plume created by the collision of the Deep Impactor with Comet Tempel 1 at .84-second intervals.. Students measure the two axes of the ellipse and calculate the rate of expansion during the first six minutes after impact.





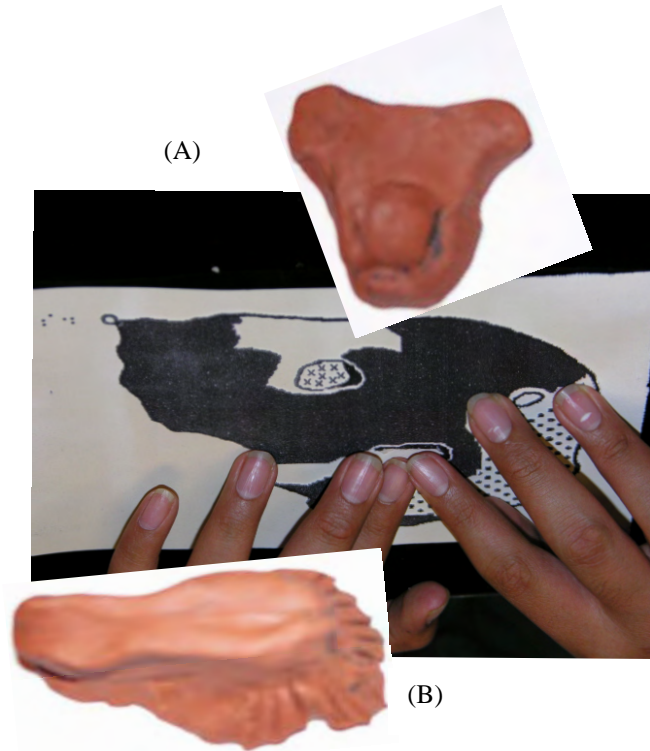
Observing a 3-D model of the comet's nucleus is one more method for helping visually-impaired students relate two-dimensional images to three dimensional objects.



The same-sized tactile graphics can be used to emphasize different properties of the same object.

In the photograph above left, a student *compares* a tactile graphic of the temperature ranges recorded on the surface of Comet Tempel 1 with that of the surface features and the regions in which surface ice was discovered. This allowed him to *make the connection* that surface ice was found in the depressed regions where temperatures were lowest. Continued *analysis* of the temperature ranges led to the *prediction* that the sun was shining most directly on the lower right of comet's surface. It also led to the answer to the question, "How did the impactor know where to collide with the comet?"

Although sighted students can easily make these observations, they are not so readily apparent to visually-impaired students.



Although differences in elevation were identified by filled, wide lines in the tactile graphics, they are difficult for students to interpret. Clay models of the depression in one smooth region (A) and the elevated smooth region falling off into an escarpment (B) help students form mental images as they read the description and observed the graphic