Sparking Discussion through Visual Thinking

Strategies for adapting Visual Thinking Strategies for use in the science classroom

By Tarah Connolly, Ron Skinner, and Danielle Harlow

"While the activity of examining art is not so different from a young person following a line of ants along a sidewalk to see where it leads, it is also how a scientist studies climate and a historian pieces together the past" (Yenawine 2013, p. 13).

Engaging students in conversations around science and engineering design can be challenging. Sparking such conversations during field trips at an interactive science center has additional challenges. First, students vary considerably in age from day to day: We might work with first graders one day and sixth graders the next. Second, students are on the field trip for a short time. Therefore, we must establish norms without spending much time teaching expectations around science and engineering discourse. These challenges motivated us to implement a framework that would work effectively across age groups and immediately engage students in discussion and dialog during our *Engineering Explorations*, 50-minute engineering design activities implemented as field trip programs in our museum classroom. This framework adapts well to classroom settings and is easily implemented as a lead-in to any number of science or engineering design activities.

Visual Thinking Strategies

We adapted questions from Visual Thinking Strategies (VTS) (Housen 2002; Yenawine 2013) to elicit student ideas and prompt discussion. VTS is a structured way of facilitating discussions around images (Housen 2002) that was developed for art museums to help visitors learn to observe, find meaning, and support their ideas with evidence. VTS has been used in classroom settings from preschools to medical schools and is grounded in constructivist ideas about learning. The originator of VTS, Abigail Housen (1999) states, "... good teaching is more than imparting pre-digested information which is not relevant to the student… student learning occurs when the learner is actively making new constructions, building new kinds of meaning in new ways" (p. 5). Those same constructivist ideas inform *Next Generation Science Standards*–aligned science instruction, which guide our Engineering Explorations.

Our use of VTS is built around three questions asked in the following order:

(1) What do you think is going on in this picture?

(2) What do you see that makes you say that?

(3) What more can we find?

VTS requires close observation and evidence-backed claims, which mirrors important practices in science and engineering. To adapt this discourse tool for science and engineering, the visual that the educator selects might be a still image, a video clip, or a live demonstration. It should prompt discussion about key ideas that are built upon during subsequent activities or prompt questions that motivate further investigation. In this article, we describe one example of a VTS conversation motivating an engineering design activity done with upper elementary school students.

The goal of this activity was to set the stage and elicit students' ideas that would be built on when students later solved an engineering design problem. In the design challenge, students would collaboratively design a multi-layered patch to repair a greenhouse on the Moon. This required students to grapple with the effects of placing objects of different materials in the path of a beam of light (1-PS4-3) and with the idea that energy is transferred from one place (the Sun) to another (the greenhouse) by light (4-PS3-2). Thus, our VTS activity focused on ideas about infrared radiation and visible light and the degree to which these are transmitted through various materials.

Eliciting Ideas

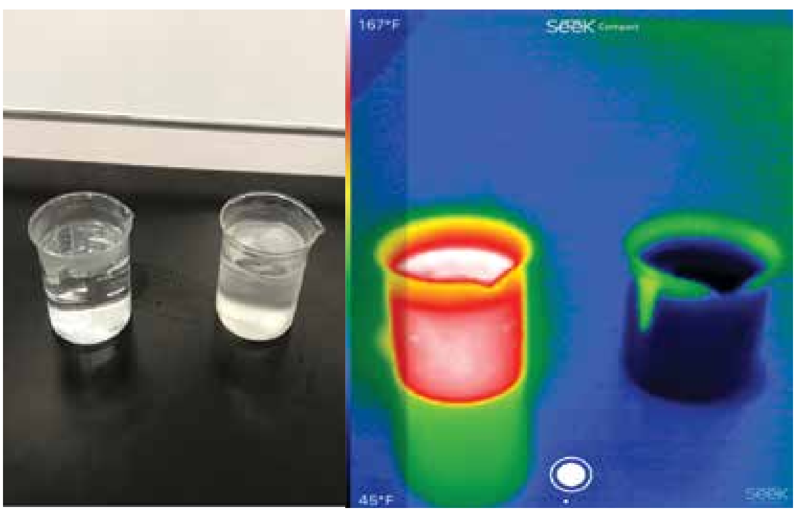
To elicit student ideas about heat, light, and the differences in how they interact with materials, we began with a demonstration. The students observed two beakers, one that contained hot water (keep students at a safe distance) and one that contained cold water and ice cubes. An infrared camera projected the thermal image of the beakers, allowing students to see the materials and their thermal images simultaneously. The facilitator then covered the beakers with a plastic bag, preventing students from seeing the beakers. Surprisingly, the thermal image stays virtually unaffected. The facilitator then removed the plastic bag and covered the beakers with a clear acrylic sheet. The students could clearly see the two beakers, but the thermal image showed one solid color across the entire screen.

Safety note

Students should be cautioned that the heat lamp is very hot. They should not touch it nor look directly into it. We placed the heat lamps in specially constructed boxes to prevent students from touching the lamp. Infrared thermometers have a laser that indicates the location that the temperature is being detected. We covered the laser with black electrical tape to avoid students pointing it toward another student's eye.

FIGURE 1

Condition 1: Beakers of hot water and ice water visible on the table (left) and the thermal image of the beakers of water (right).



PHOTOS COURTESY OF THE AUTHORS

Facilitator: "We're going to spend one minute looking silently at this projection from this camera (see Figure 1, p. 45). *I'm going to change some things about the setup while you look. Make observations silently to yourself, and then we're going to talk about it."*

One minute passes, in which the facilitator covers the beakers of water with a plastic bag (opaque to visible light, transparent to infrared) (see Figure 2) and then an acrylic sheet (transparent to visible light, opaque to infrared) (see Figure 3).

Recreating this phenomenon requires two clear beakers or glasses, one full of cold water and one full of hot water, a black garbage bag, a piece of clear acrylic, and an infrared camera. Flir One (*www.flir.com*) and Seek (*www.thermal.com*) make attachments for smart phones and tablets that cost between $100–$500. Infrared cameras are used for construction applications (seeing heat leaks in buildings), serveillance (seeing people in the dark), science, and other industries. Teachers may be able to borrow infrared cameras from a local university or construction company, or they can be rented from home improvement stores in some areas.

Sample Conversations

In this section, we illustrate the types of ideas that this demonstration and conversation elicited among students, pulling dialog from multiple classrooms. Each case represents a claim that students typically make during the VTS discussion along with the types of observational evidence they use to support their claims. In each conversation, the VTS questions are boldfaced.

Elicited idea 1: Heat is represented through color

Facilitator: **What do you think is going on here?**

Student: It looks like the cup on one side has ice.

Facilitator: **What do you see that makes you say that?**

Student: I can see the cup, and it has ice in it. I don't know how cold the other one is but I think it doesn't have ice.

Facilitator: Okay, so you see that one beaker is full of ice. **What more can we find?**

Student: In the picture, it is white but the icy one is blue.

Student: One is hot and one is cold.

Facilitator: **What do you see that makes you say that?**

Student: The different colors are, one is hot and one is cold. The colors show temperature.

Facilitator: So you're seeing that colors in this image indicate the temperature of the objects.

The students in this example used both the physical materials (beakers of water) and the thermal image to provide evidence for claims that one beaker was hot and the other was cold. Following the suggestion that the projected image shows heat, other students joined in, discussing what they knew about representations of heat. They cited familiarity with scales on a thermometer, infrared applications (like night vision goggles), and occasionally exhibits around the museum that use infrared cameras. They also pointed to the temperature scale shown on the projection, providing explicit evidence for their claims that color represents heat.

This conversation allowed students to generate the relationship between light and heat, which the facilitator renamed as a single concept: *infrared radiation*. Radiation is the term used when energy is transferred from one object to another without touching (NSTA, n.d.). In this case, the heat is transferring from the beaker to the sensor in the camera. The claim that heat is represented by color highlights the idea that infrared radiation, which we experience as heat, is a part of the light spectrum that infrared cameras can detect and represent.

Elicited idea 2: Different materials have different effects on how much heat and light pass through.

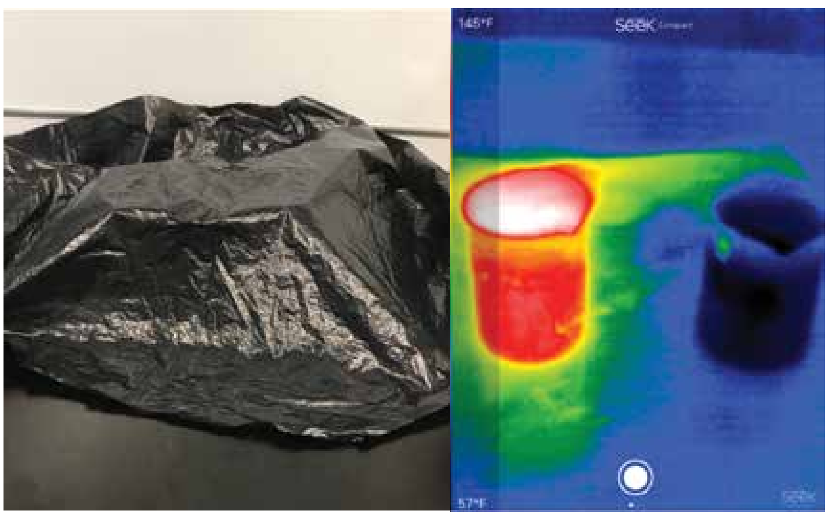
Facilitator: **What do you think is going on here?**

Student: The color of the material is changing what heat goes through.

Facilitator: **What do you see that makes you say that?**

FIGURE 2

Condition 2: Beakers of hot water and ice water covered in black plastic bag (left) yet visible in the thermal image of the beakers of water (right).



PHOTOS COURTESY OF THE AUTHORS

Student: When you put the clear plastic between the camera and the beakers, it all became the same color, but the black one let all the heat go to the camera.

Facilitator: **Okay, what more can we find?**

Student: The black plastic was thinner, so we could see the cups still.

Facilitator: I hear you saying that something about the material changed what we were able to see on this camera that uses color to show heat. **What more can we find?**

Student: Maybe the black plastic is a different kind of material.

Student: The heat can get through the black plastic but not the clear one.

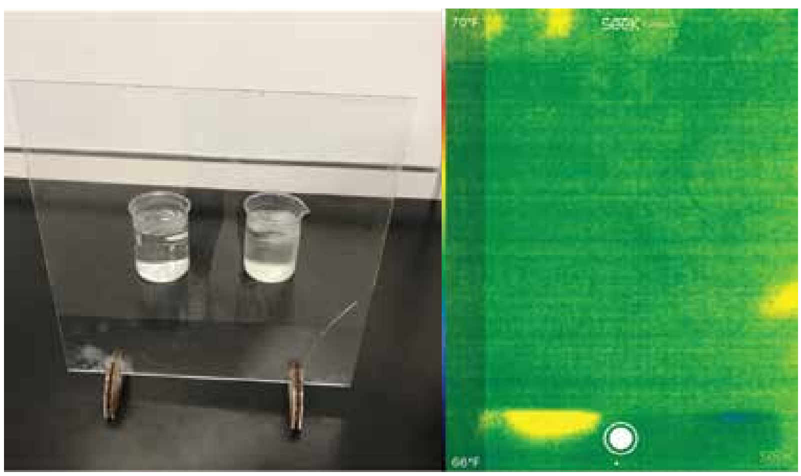
This VTS conversation elicited student ideas about material properties that pertained to the design challenge. As students tuned into the observation that different materials changed the colors shown in the thermal image (which was established as a representation of heat), the facilitator used this discussion to introduce the goals and constraints of the design challenge. Furthermore, students, and facilitators established a common point of reference around the phenomenon of selective filtration, which is the idea that materials can allow some wavelenghts to pass through while blocking others. That is, the materials filter certain wavelengths. The students experienced this by observing that the trash bag allowed infrared heat to move through it, but not visible light, while the acrylic allowed the visible light to pass through, but not the infrared heat.

Building on a VTS Conversation

Teachers can plan instruction that builds on the partial ideas that their students articulate and begin with students' everyday language to help them access the content and build academic language through the lessons. In this case, following the VTS conversation, the facilitator introduced the engineering challenge, and the students executed three rounds of design. The goal was for students to practice optimizing design solutions (ETS1C), to think about the ways that heat and light are transferred (4-PS3-2), and the ways in which materials interact with light and heat (1-PS4-3). Using a model of the Sun's visible and infrared radiation (a heat lamp), measuring tools, and a variety of sample materials that transmit light and infrared radiation at various levels like plastic bags, colored film, and acrylic, students worked to repair a model of a lunar greenhouse. Students combined materials to keep the intensity of visible light and infrared radiation within given tolerances (see Figure 4, p. 48). Some aspects of the design task were simplified to focus the activity. Rather than building a full greenhouse structure, students placed materials in the path between the heat lamp and the measuring tools. The materials were pre-cut and mounted so students could rapidly test different combinations. During the first two rounds of design, students considered only one criterion at a time. First, they focused on keeping the temperature reading as close to 70° F as possible using a non-contact digital infrared thermometer (We used Masione Temperature Gun, $33. Similar products are available from Helect, Etekcity and other vendors for $14–$33). During the second round, they focused on keeping the lux meter (a tool to measure light intensity, available for $14–$33 from vendors such as Leaton or Dr. Meter on *Amazon.com*) reading as close to 450 Lumens as possible. During the third round, they considered both sets of constraints and optimized their solution. In all three rounds, the students recorded the materials they used and either the temperature reading (for round 1) or light intensity (for round 2) or both the temperature and light readings (in round 3) in a data table. Throughout, the facilitator encouraged students to use the observations and inferences from the VTS discussion to inform their investigations and decisions about materials that filter light and heat to varying degrees. The activity can be used to assess students' understanding of Engineering Design 3-5ETS1-2. We have shared a rubric online that could be used for any engineering design task that requires students to compare between multiple solutions (see NSTA Connection).

FIGURE 3

Condition 3: Beakers of hot water and ice water visible with a clear plastic (acrylic) sheet placed between beakers and camera (left) beakers of water are no longer visible in thermal image (right).



PHOTOS COURTESY OF THE AUTHORS

Recommendations for Science and Engineering Activities

1. **Think carefully about the images.** Select images to elicit ideas about the science content or the engineering challenge. They should be puzzling enough to give students an opportunity to wonder about what is going on and allow for a range of inferences.
2. **Consider different media.** VTS questions can be used around short videos, live demonstrations, or even out of the classrooms on field trips to natural or designed environments.
3. **Ask students to observe quietly before talking.** Providing time for students to observe quietly affords students the opportunity to gather their own thoughts and wonderings before being influenced by other students' ideas.
4. **Don't judge students' responses.** Students may have ideas about what is going on that differ from what you expect. Press for evidence on ideas, but do not evaluate them (negatively or affirmatively) during the VTS stage.

FIGURE 4

Students combined materials to keep the intensity of visible light and infrared radiation within given tolerances.

5. **Revoice or rephrase the ideas presented.** Revoicing or rephrasing ideas can be used to repeat ideas that are shared quietly or that might not be understood clearly by all students, emphasize a specific part of an idea, or clarify or introduce language.
6. **Differentiate.** The open-ended nature of the VTS questions allows for diverse responses. Provide multiple representations of the questions. In addition to asking the questions in discussion, visually display the written questions. To provide access to VTS for students who are visually impaired, provide verbal description (without interpretation) of the imagery.

Adapting for the Classroom

The activity presented here occurred in a museum classroom with students visiting on a field trip. The lesson fit into a 50-minute period, typical of classroom schedules, and covered science and engineering content and practices based on current classroom standards. We present this activity as one context in which Visual Thinking Strategies has value for introducing scientific phenomena and sparking discussion, but VTS can be used for a range of science and engineering concepts. If your class is exploring balanced and unbalanced forces (PS2-1), you might use VTS to discuss a video of children on a seesaw. If your class is working on ecosystem dynamics (LS2-1), you might lead a VTS dialog about an image of decayed fruit. For engineering, you might use an image to represent a situation that people want to change which students can identify and develop solutions for (ETS1-1). VTS provides a simple facilitation strategy to encourage students to make inferences and support their ideas with evidence, and it can be a lead-in to any number of science or engineering activities in a classroom setting. VTS allows teachers to quickly engage students in discussion and dialog and elicit students' ideas, provides students with opportunities to practice supporting their claims with evidence, and supports the entire class in developing a shared point of reference for building understanding of concepts and processes related to subsequent science and engineering activities. ●

REFERENCES

Housen, A.C. 2002. Aesthetic thought, critical thinking and transfer. *Arts and Learning Research* 18(1): 2001–2002.

Housen, A.C. 1999. Eye of the Beholder: Research, Theory and Practice. Presented at the conference of "Aesthetic and Art Education: A Transdisciplinary Approach," sponsored by the Calouste Gulbenkian Foundation, Service of Education September 27–29, 1999, Lisbon, Portugal. *https://vtshome.org/wp-content/uploads/2016/08/Eye-of-the-Beholder.pdf*

NSTA (no date), SciPacks and Science Objects: Thermal Energy, Heat, and Temperature Science Object. Retrieved from *https://learningcenter.nsta.org/lcms/default.aspx?a=groupedit&gid=909&tid=299&soid=59*

Windschitl, M. 2017. Rapid Survey of Student Thinking (RSST). Retreived from *https://ambitiousscienceteaching.org/rapid-survey-of-student-thinking-rsst/*

Yenawine, P. 2013. *Visual thinking strategies: Using art to deepen learning across school disciplines*. Cambridge, MA: Harvard Education Press.

Connecting to the *Next Generation Science Standards* (NGSS Lead States 2013)

Standard

4-PS3 Energy

www.nextgenscience.org/dci-arrangement/4-ps3-energy

- The chart below makes one set of connections between the instruction outlined in this article and the *NGSS*. Other valid connections are likely; however, space restrictions prevent us from listing all possibilities.
- The materials, lessons, and activities outlined in the article are just one step toward reaching the performance expectation listed below.

Performance Expectation

4-PS3-2. Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.

DIMENSIONS	CLASSROOM CONNECTIONS
Science and Engineering Practice	
Analyzing and Interpreting Data	Students define problem constraints, collect data on heat and light that is transmitted through materials, and use data to determine which material transmits more light. Students interpret thermal image to understand that color represents heat.
Disciplinary Core Ideas	
PS3.A: Definitions of Energy Energy can be moved from place to place by moving objects or through sound, light, or electric currents. **PS3.B: Conservation of Energy and Energy Transfer** Energy is present whenever there are moving objects, sound, light, or heat. Light also transfers energy from place to place.	Students observe that heat and light are both radiated by beakers of water. Students observe that a heat lamp transmits light and heat to a location a meter away.
Crosscutting Concept	
Patterns	Students observe color patterns in thermal images to make inferences about how hot and cold areas are represented.

Tarah Connolly is the Curriculum Specialist, and **Ron Skinner** is the Director of Education, both at MOXI, The Wolf Museum of Exploration + Innovation in Santa Barbara, California. **Danielle Harlow** (***dharlow@education.ucsb.edu***) is a professor at the University of California, Santa Barbara.