SCIENCE of art
MUSEUM OF GLASS

Curriculum
Mobile Hot Shop
Glass, Art, Science, History & Communication

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Museum of Glass ⊙ Mobile Hot Shop

FUSING DISCIPLINES

Glass, Art, Science, History and Communication in a unique fusion of creativity…

Dear Educator,

Creatively fuse disciplines in your classroom! Art, science, history, and communication merge as we study the world of glass and glass in our world. This learning process is designed to inspire you and your students to think deeply about connections between art, science and history through observation and inquiry—processes shared by artists, scientists, and historians.

Pre-Mobile Hot Shop activities, student reading, and graphic organizers can help prepare your students for their Mobile Hot Shop experience. Also guided student observation and inquiry when the Mobile Hot Shop is visiting can build insight into the art of glass blowing and the art of collaboration.

A post-Hot Shop activity engages students in a collaborative creative process where they design and present a plan for a glass sculpture. This work as a design team helps students develop communication skills and apply understandings of the art and science of glass.

Along with this packet, we have extensive additional information on our website about glass blowing and working with hot glass. Visit **museumofglass.org/education**. Also, In the Virtual Hot Shop, your students can get a preview of glass blowing online as they participate in a process step-by-step until they create a finished work of art! Along the way they can also choose to read more and view video clips of the process live.

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EALRs & GLEs

The Arts

1.3 Apply audience skills in a variety of arts settings and performances.

2.1 Apply a creative process.

2.3 Apply a responding process to an arts presentation.

4.2 Demonstrate and analyze the connection between art and other content areas.

4.4 Understand that the arts shape and reflect culture and history.

Science

1.1 Understand how properties are used to identify, describe, and categorize substances, materials, and objects and how characteristics are used to categorize living things.

1.2 Know and apply scientific concepts and principles to understand the properties, structures, and changes in physical systems.

1.3 Understand how interactions within and among systems cause changes in matter and energy.

3.1 Apply knowledge and skills of science and technology to design solutions to human problems or meet challenges.

3.2 Analyze how science and technology are human endeavors, interrelated to each other, society, the workplace, and the environment.

Social Studies

3.2 Geography: analyze cultural interactions.

5.2 Social Studies Skills: Use inquiry-based research.

Communication

1.1 Use listening and observation skills to focus attention and interpret information.

2.2 Use interpersonal skills and strategies in a multicultural context to work collaboratively, solve problems, and perform tasks.

Before

Your Mobile Hot Shop Visit

Supporting Information, Essential Questions and Observation/Inquiry Process

FUSING DISCIPLINES

STUDENT READING: OVERVIEW

ART

Why do artists make art with GLASS?

Line, **shape/form**, **color**, **texture**, and **space** are all visual art elements that can be explored in glass. Glass is the ordinary functional jars we use every day or the exquisite goblets of kings. Glass can be solid or fragile, sharp or smooth, shiny or dull, light or heavy, **transparent** or **opaque**, inviting or scary...It can transform and interact with light as no other material on earth can. And, it can be shaped and used in infinitely creative ways.

Sculpture (art that is three-dimensional) offers us multiple points of view and can interact with its environment. Glass sculpture, like any art form, can communicate ideas, feelings and beliefs. **Scale**, a sculptural term for size in relationship to other objects, can be **monumental** (huge!), **life size,** or **miniature** in glass sculptures.

It is impossible to blow or sculpt hot glass objects larger than a human being on a **blowpipe**, although there are a handful of artists who are pioneers using specialized equipment and highly trained teams. The **casting** process—pouring hot glass into a mold--offers artists an avenue to create collossal scuptures made in one piece or in several interlocking pieces.

What are some of the challenges in making art with GLASS?

Safety! Glass is melted in specially designed furnaces—In the Mobile Hot Shop it is being melted at approximately 2150° Fahrenheit. When glass is hot, you can manipulate it in many ways, but you cannot touch it! Chemicals used to make glass can be toxic. Some of the most beautiful glass colors in their raw chemical state are also some of the most toxic to humans!

Precautions must be taken when you mix and melt **batch**—the raw ingredients that become glass. Many chemicals, if they are inhaled, ingested or come in contact with your skin, can be harmful. Protective safety equipment is essential—respirators, safety goggles, gloves and special clothing are used for mixing batch. Face shields and kevlar gloves, like those used by fire-fighters, are used in **charging** the furnace (loading the batch into the fire).

Batch: A recipe of chemical ingredients is melted to make into glass. Which ingredients used depends on how the glass will be formed and what colors and amount of transparency it will have. How toxic, expensive, and readily available raw materials are impact choices for ingredients.

It takes expensive, specialized equipment in order to melt glass including fans for ventilation and safety, storage for batch, and the furnace itself. It is also takes a lot of energy to run a furnace--costly utility bills!

The technical skill required to make an artistic idea come to life in hot glass can take years to develop. Imagine taking a glowing blob of molten glass and turning into a beautiful piece of art. Artists also choose to work with glass by cutting, grinding, polishing and combining it with other art materials.

Students Engage!
How do we define art?
Think about all of the glass in your world... Describe functional glass objects that you use often. Describe glass objects that are used only for decoration. Are any of these glass objects "one of a kind"? Do they express an idea or a feeling? Can glass be functional and a decoration or art?

SCIENCE

Where does GLASS come from?

Volcanos produce glass naturally. Obsidian, or volcanic glass, is formed when a type of lava (felsic—which contains a high amount of silica and feldspar) is cooled to form glass.

The kind of glass used here in the Mobile Hot Shop is called **Soda-Lime** glass. Special sand free from impurities (known as silica), that is mined, is the main ingredient in glass. Other ingredients play an important role also: Sodium Oxide (called soda ash) lowers the melting temperature of the silica. However, the soda ash makes the glass water soluble—not so suitable for making flower vases! To make the glass stable and not water-soluble, Calcium Oxide is added (known as dolomite or lime). Other ingredients are also added: Aluminum Oxide which gives glass more structural strength and Zinc Oxide which makes glass more brilliant (sparkly). Different colors are created by adding chemicals to glass:

Glass Colorant Examples

Cobalt carbonate ($CoCO_3$)	deep dark blue ("cobalt blue")
Chromium oxide (Cr_2O_3)	emerald green blues, greens, and reds
Copper oxide ($CuCO_3$)	red/deep red
Magnesium oxide (manganese)	purples, blue/violets, and browns
Silver ($AgNO_3$)	various colors from yellows to blues
Gold chloride ($AuCl_3$)	ruby red
Iron (Fe_2O_3)	greens and browns
Cadmium sulfide (CdS)	oranges
Cadmium selenium (CdSe)	deep ruby reds

Other ingredients affect the characteristics of glass: for instance, Lead Oxide is used instead of Lime in Waterford Crystal to create a softer, heavier glass that interacts with light differently.

Transparent: a material that transmits light in straight lines without distorting images.

Translucent: a material that transmits light in diffused directions distorting its path.

Opaque: a material that absorbs or reflects light, not allowing light to pass through it.

What are the physical properties of GLASS?

Scientists have found ways to utilize glass in ever advancing technologies. Glass can be a liquid or a solid. Glass expands and contracts as it is heated and cooled. Hot glass can be formed by stretching, blowing, pouring, casting, fusing, slumping and pressing. Cold glass can be cut, ground, engraved, etched or polished.

Glass is a material that interacts in many ways with light. It can **transmit**, **absorb** or **reflect** light. It can also **refract**, or **diffract** light in ways that change the color and quality of the light as well as shape images received by the brain.

Glass was instrumental in the early **science of optics** (light and perception): in 1666 Isaac Newton (1642-1727, England) performed a famous series of experiments in which he shined white light through prisms (triangular shaped pieces of glass). Prisms create a **spectrum** (a term coined by Newton) similar to that of the rainbow. Newton's experiments showed that **white light** is composed of a continuous range of spectral colors (hues), which he designated red, orange, yellow, green, blue, indigo, and violet.

Refraction: bending of a light beam that occurs at the boundary between one material/medium or another.

Diffraction: a light beam bending and spreading out as it moves around an object or through a narrow opening(s).

Reflection: rays of light bouncing off a surface.

Glass **molecules** are not organized and form a random assortment with little spaces in-between. These spaces allow light to pass through making it transparent. Glass needs to cool very slowly because of it's amorphous molecular structure (it does not form crystals). This process is called **annealing.** During annealing, the molecules of glass have a chance to flow and line up when cooling. When glass cools too quickly, molecules stick together in random directions and the outer layer cools more quickly than the inner layers. This causes internal stress to glass and can cause cracking and instability.

Many types of glass have been developed for every day and industrial use. In **Pyrex** glass cooking dishes, the chemical composition of the glass allows it to melt at a higher temperature than soda lime glass. It can also withstand rapid heating and cooling. It is so strong that it was used for windows in the Gemini and Apollo spacecrafts and the giant lens of the Hubble Space telescope. **Tempered glass** or "safety" glass is used in automobile windshields: it has increased strength and can break into smaller pieces because the glass is of special composition and there is a layer of plastic sandwiched in the middle. **Glass laminate** used in buildings also has a similar structure.

Glass plays a major role in technology: flat screen televisions are made using glass—also the CRT (Cathode Ray Tube) that produces an image is made with glass. Besides glass lenses for projection, TV's like **LCD** (liquid crystal display) or **DLP** (digital light processing) utilize a device called a **DMD** (digital micromirror device) which contains millions of micro-mirrors reflecting light from a lamp. These mirrors flip back and forth quickly to create the colors, shapes and depth seen in the television's picture.

Fiber optic cable is made up of bundles of tiny strands of glass. Glass transmits (allows to pass through) light by allowing light to enter through gaps in molecules. It has to hit just the right angle to escape again—otherwise it will travel the length of the glass fiber. Energy travels down these tiny strands of glass providing fast digital data transmission to your TV, computer, phone, or other devices.

Students Engage!
How do scientists come up with ways to use glass in advanced technology?
Where else is glass used in industry and technology?

HISTORY

How old is GLASS? Historians study ancient glass to learn about the people who made it. Because glass can last forever, it is considered one of the only truly **archival** art-making materials. It is believed that the first glass was made 5000 years ago. Glassblowing began around 2000 years ago in the Middle East and quickly spread.

The **Romans,** in their conquering days, established glassmaking "factories" across the far reaches of their empire. Glass was a hot commodity to trade: the interaction of world cultures throughout history can be studied through the objects and glass techniques that were traded and shared. **Islamic** glass created in the area that is presently Iran is 600 – 1000 years old. It is considered technically "advanced" by today's standards since it shows highly developed skill not just in glassblowing, but in carving, etching, and enameling as well.

Stained Glass windows in churches began to appear around the 12th century in Western Europe. The majority of people at that time were not trained to read or write, but "read" the pictures in the windows as a way to understand the stories and the teachings of the Bible.

From the 11th to13th century, two dominant styles of glassmaking emerged in Europe: Waldglas in the north, and Venetian "Cristallo" in the south. **Waldglas** or "forest glass" houses were scattered throughout northern and central Europe. Their focus was on creating bottles and containers for everyday use, unlike the one-of-a-kind specialties for the nobility developed Venice.

Further to the south in **Italy**, in 1291, by governmental decree, the glassmakers and their hotshops were moved from the city of **Venice** to the nearby island of **Murano**. One reason was to contain the threat of fire and another was to isolate and guard the secrets of their highly evolved glass blowing techniques.

The glass produced in Venice was typically thin-walled **vessels**, expertly crafted goblets and all types of **canework** that bedazzled the kings, queens, and heads of state throughout Europe. Venetian glass was highly sought-after. The glassblowers of Murano attained great wealth and nobility status during their heyday from the 14th through 18th centuries.

Glass Arrives in America Glassmaking was America's first industry--established in Jamestown, Virginia in 1609. English-style glassmaking techniques were brought from England and remained an influence for a couple of centuries in North America.

During the **industrial revolution**, glass objects were being mass-produced (still by hand) by the thousands. Moldblowing (a technique developed by the ancient Romans) is a quick and easy way to produce hundreds of objects that are identical in shape and style. Mold blowing reached its peak when the first fully automated bottle-making machine was produced nearly 100 years ago.

ART of the Studio Glass Movement
The Golden Age of Glass is NOW. Ancient glass working techniques have been brought out of glass factories from all over the world and are in the hands of artists.

The Studio Glass Movement In 1962, Harvey Littleton's discovery that glass could be melted at lower temperatures in smaller furnaces than were traditionally used in large factories fueled the Studio Glass Movement. Littleton, along with Dominick Rabino, are commonly considered the founders of the modern Studio Glass Movement.

Since then, contemporary artists have been exploring avenues of glassmaking free from the limitations of mass production. Scholarships helped fund travel for a number of American artists to study glassmaking abroad including Dale Chihuly, Ben Moore, and Richard Marquis.

Lino Tagliapietra, Venetian glass master and internationally acclaimed artist, has greatly influenced American artists since he has spent numerous years teaching and collaborating with American artists hungry for knowledge of traditional glassworking techniques.

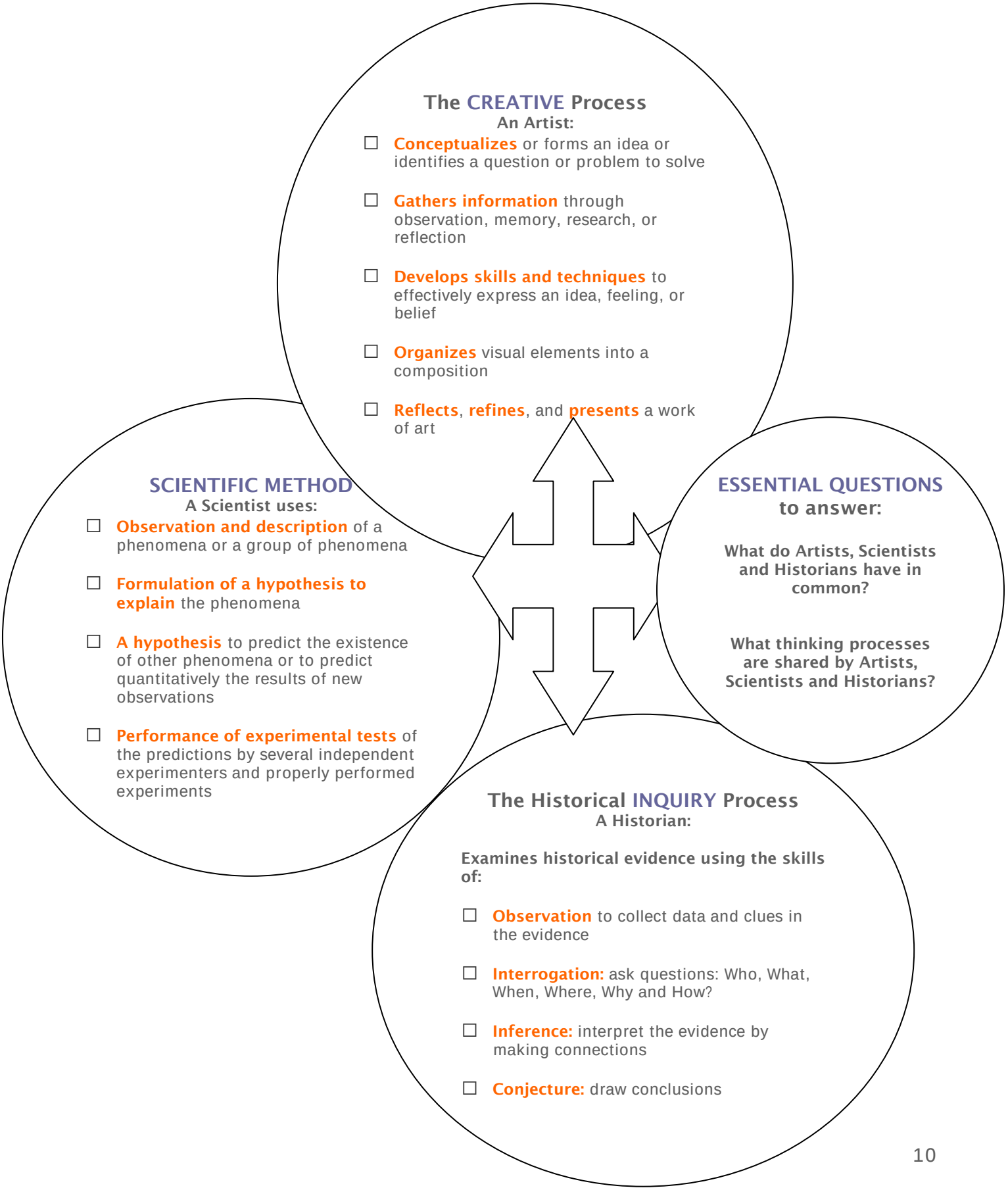
Glassblowing: An International Language Glassblowing has undergone many changes throughout time. Glassmaking is a global activity today. Each country has its own unique way of making glass: Many styles of glassblowing are the product of trade secrets passed down through families and guilds (arts and crafts unions) throughout centuries. These techniques were often developed in isolation from the countries that bordered them. With the advent of the jet airplane, international commerce, and communication through technology on a global scale, the borders and differences that separate our countries are getting thinner and more transparent every day.

The studio glass movement that began in the United States some thirty years ago established some lines of communication that continue strong today. The sharing of information in the world of glass is at an all-time high, and is constantly growing.

Students Engage!
How old is the glass around you?
Glass objects are some of the most highly collected objects in the world! Think about all of the glass objects in your kitchen cabinet, or maybe your grandmother's or your great-grandmothers kitchen cabinet. Visualize one of those objects: Where did it come from? How old is it? Who made it? How do you think it was made? Was it blown, cast, cut?

FUSING DISCIPLINES:

WHOLE CLASS DISCUSSION & BRAINSTORMING



STUDENT PRACTICE IN OBSERVATION AND INQUIRY

Choose a work of art and answer questions below…





OBSERVE, DESCRIBE, ANALYZE

Color?

Texture?

Shape/Form?

Size/Scale?

Functional/Non-functional?

Transparent, opaque or translucent?

How does it interact with light?

FORM A HYPOTHESIS, INTERPRETATION

What does the art remind you of?

Where did the artist look for inspiration?

Does the art communicate an idea, feeling, or belief?

If yes, what is communicated? What evidence did you record that supports your idea?

How do you think the art was created?

Pre-visit Reflection/Student Self-Assessment

What makes glass different than other art making materials?

What are some of the ways that glass interacts with light?
What are the primary ingredients in glass? What gives glass color?
What discoveries have been made by scientists using glass?

How long has glass been in existence?
Why is glassblowing considered an international language?

What do artists, scientists and historians have in common?
What thinking processes do artists, scientists and historians share?

During

Your Mobile Hot Shop visit

Observation/Inquiry process in Action

FUSING DISCIPLINES:

OBSERVATION AND INQUIRY: DURING THE MOBILE HOT SHOP VISIT

GLASS blowing

A team effort:

Gaffer The leader of the glassblowing team—the most trusted and experienced member.

1st Assistant/Pole turner Reheats, rotates the blowpipe: follows every movement and direction of the gaffer. Has years of experience.

2nd Assistant/Starter Does the initial gather of hot glass and starts the glass piece. Shields the gaffer, torches, brings bits and wraps, bench-blows.

3rd Assistant/Bit or Punty Boy/Girl Entry level position--Does starts and gathers, opens furnace doors, runs errands, clean out pipes, sweeps.

ESSENTIAL QUESTIONS to answer:

What are the traits of an effective collaborator?

What makes a successful team?

QUESTIONS FOR THE MOBILE HOT SHOP

About teamwork:

About creativity:

About glass:

OBSERVING THE MOBILE HOT SHOP

Describe the steps you observed:

1.

2.

3.

4.

5.

6.

Describe the ways that the glass blowing team communicated with one another:

Describe how the glass changed from start to finish:

FUSING DISCIPLINES:

STUDENT DESIGN TEAMS EXPLORE COLLABORATION AND CREATIVITY

Description:
4-5 students collaborate as a design team to visualize, describe, and represent (in drawing/collage) an original glass sculpture from two points of view

Student Objectives:

Collaborates effectively as a team
Student Team Assessment Checklist:

- ☐ Assigns design team roles
- ☐ Equally contributes ideas
- ☐ Equally assumes workload
- ☐ Reaches consensus
- ☐ Completes design in designated time (60 minutes suggested)

Creates a 2-dimensional design for a 3-dimensional glass sculpture
Student Team Assessment Checklist:

- ☐ Conceptualizes/visualizes sculpture guided by questions
- ☐ Makes artistic choices guided by questions
- ☐ Draws, cuts, and/or layers shapes in translucent, transparent and opaque paper to represent glass sculpture
- ☐ Uses good craftsmanship using clean cutting, firmly adhered paper, no glue residue
- ☐ Shows glass sculpture from more than one point of view in design (two sides; top and one side; close up detail and further away...)
- ☐ Documents process by answering guiding questions on following page

The CREATIVE Process
An Artist:

- ☐ **Conceptualizes** or forms an idea or identifies a question or problem to solve
- ☐ **Gathers information** through observation, memory, research, or reflection
- ☐ **Develops skills and techniques** to effectively express an idea, feeling, or belief
- ☐ **Organizes** visual elements into a composition
- ☐ **Reflects**, **refines**, and **presents** a work of art

Presents
Student Team Assessment Checklist:

- ☐ Describes creative process step by step
- ☐ Describes challenges and successes of collaboration

Materials:
Transparency film, translucent papers: tracing paper, vellum, or wax paper; white and colored card stock or fadeless paper; pencils, colored fine, broad-tipped markers; glue sticks, scissors

Students Engage!
Where do we see effective collaboration?
Every time you see a movie or television show, listen to music, or watch a football or baseball game you are watching collaboration in action. Think of more examples of collaboration. Ever played music in a band or orchestra, sang with a choir, played on a soccer team?

POSSIBLE DESIGN TEAM ROLES

Title	Job	Student Name
Scribe	Documents process in writing	
Draftsperson	Sketches ideas as they occur	
Craftsperson	Cuts/glues shapes	
Facilitator	Guides discussion/builds consensus	
Spokesperson/Presenter	Shares process with whole class	

CONCEPTUALIZE/VISUALIZE

What do you want your sculpture to remind you of?

Where is your team looking for inspiration? (nature, humans, machines...)

What an idea, feeling, or belief does your team want to communicate? (joy, chaos, serenity...),

How will your artistic choices support your idea? (Color, line, shape, texture, shape/form)

How will your glass sculpture be created? (blown, cast, fused?)

ARTISTIC CHOICES

Color?

Texture?

Shape/Form?

Size/Scale? (monumental, life-size, miniature?)

Functional/Non-functional?

Transparent, opaque or translucent?

How will it interact with light? (reflect, transmit, refract/bend light?)

Resources

Glossary, References, Web Links

and More

Ed Schmid, artist, glass expert and author is the source for nearly all information provided in this packet.
Here, he compares batch to a chocolate chip cookie recipe...

The following information will introduce you to the main ingredients used in making a soda-lime based glass suitable for blowing and casting:

Soda-lime Glass Recipe Chocolate Chip Cookie Recipe

72.0% Silica sand SiO_2	2 cups flour
14.9% Soda Na_2O	3/4 cup white sugar
7.9% Lime CaO	3/4 cup brown sugar
1.8% Alumina Al_2O_3	2 eggs
1.0% Lithium Li_2O	2 sticks of butter
1.0% Zinc Oxide ZnO	1/2 teaspoon salt
0.5% Barium BaO	3/4 teaspoon baking soda
0.4% Potassia K_2O	2 teaspoon vanilla extract
0.2% Antimony Sb_2O_3	1 bag of chocolate chips

The Sand (or the flour in our cookie recipe)

O.K. we all know that sand (a.k.a. silica, or silicon dioxide) is the main ingredient in glass. (Just like flour is the main ingredient in a cookie mix). It is also called a network former by chemists.The sand's chemical composition, its size, shape and method by which it combines with the other ingredients, all play important roles in melting glass. In the United States areas in Pennsylvania, West Virginia, and the Mississippi Valley are mined for their quality and purity of glassmaking sand. Sand by itself melts at 3110°F, so it's a good idea to try and lower the sand's melting temperature. You need something to make it flow. You need what's known as a flux.

The Flux-Soda & Lime (like the wet ingredients in our cookie recipe)

Fluxes are present in virtually all glass formulae. To flux the sand, lower it's melting temperature, and make it kinda gooey, we use soda ash (Na2O) 14.9% soda to be sorta precise.(With cookies you might add 2 sticks of butter). The problem is, if we just used only soda in the glass, the results would be water-soluble. Water, as you know, is an acid and can be quite corrosive or destructive in certain situations.The other half of our soda-lime equation is the lime. It is also a fluxing agent (or network former) and increases the chemical stability and strength of the glass. In our recipe we call for an addition of 7.9 % calcium oxide, CaO (a.k.a. in their other raw states as: whiting, limestone or dolomite).

The Trace Ingredients

These are the "walk softly, but carry a big stick" constituents. Small additions of other chemicals are included in the batch to sweeten it, balance it and give it some complexity. These "intermediates" are not capable of forming glass alone; rather they assist in strengthening the glass and increasing the working time. **Alumina** (Al2 O3) is added in small amounts (1-3%) to increase the chemical durability of the glass. **Feldspar** (KNaO Al2O3 SiO2) is another compound that can impart alumina into the melt, with additional silica and potassium hitching a ride.**Lithium** (Li2O) is also a powerful flux. It is added to soften the glass, decrease its viscosity, and lower its melting temperature. **Barium oxide** (BaCO3) lowers the melting temperature, decreases the tendency towards devitrification (the formation of crystals within a glass) and offers a higher refractive index. It is also toxic. **Zinc oxide** (ZnO) is added to increase the brilliance of the glass. It works well with colors, extends the working time and also reduces devitrification.

Fining Agents

Fining agents are added to batch to assist in the melting process. When you heat batch to melting temperature of 2450'F there is a great deal of off-gassing by the oxides in the batch. This is a natural and beneficial way the chemicals will combine with each other, insuring a homogeneous mixture. As the batch begins to melt, it creates and traps air bubbles. These air bubbles are not considered desirable by glassblowers. They can be annoying to work with as well as visually distracting to the finished product. A chemical fining agent is added to the mix that will bind with the air /oxygen in the melt and either dissolves it or causes it to rise to the surface and burst. **Arsenic** (As2O3) and **antimony** (Sb2O3) are the two most common fining agents, and both of them are highly toxic.

Hot Shop Glossary

Annealer An insulated box, similar to an electric kiln, designed to cool glass slowly at a specified rate. If hot glass is cooled too quickly, the stress on the glass will cause it to be unstable and through time cause it to break. **Batch** A mixture of the basic components of glass (silica, soda, or potash and lime). When heated to its melting point, approximately 2400°F, the mixture becomes glass. **Bits** Small amounts of molten glass on the end of a punty that are brought by an assistant and applied to another hot glass form. **Block** A wooden tool that is kept wet and used to shape glass. **Blowing** The process of creating objects from hot glass. The hot glass is gathered on a blowpipe. As the object is formed the blower and/or assistants blow through the pipe creating a bubble that can take many shapes. **Blowpipe** An iron or stainless steel tube shaped for blowing glass. **Box** Another term for Annealer. **Bubble (Seeds)** Small pockets of air that form when gas is trapped in hot glass. Bubbles can be formed either intentionally during the working of the object or accidentally during the gathering or melting process. **Cap** Air is blown into the pipe and quickly closed off at the end of the blowpipe with the blower's thumb so that the hot air expands within the hot glass and/or keeps the glass from collapsing. **Casting** The process of pouring hot glass into molds of various materials, the simplest being sand. Casting can also be done from the kiln, where the glass starts in a cold state then melted into plaster/silica molds. **Charge** Shoveling batch into a furnace to melt the glass into its workable form. **Check** A crack in glass caused by improper annealing and/or compatibility of the glass and color. **Cold Shop** A workshop with equipment to grind, polish, engrave and/or cut glass and/or to add surface details to finished glass pieces. **Cullet** Cooled, glass pieces that have been previously melted and that will be recycled. **Dip** Gathering hot glass from the furnace with a blowpipe or punty. **Etching** Creating a surface design by cutting the surface of finished glass with a tool or by applying of acid. **Flameworking** The process of using a torch to heat up rods or tubes of glass that will be manipulated into different shapes. Also called lampworking. **Furnace** Equipment used for melting batch and keeping glass at a constant temperature. The temperature of the furnance ranges from 2150°F working temperature to 2400°F charging temperature. **Fusing** Heating pieces of glass until they bond. This process is achieved within an annealer. **Gather** Also called a dip. The process of collecting molten glass from the furnace on a pipe, punty or gathering iron. **Gathering iron** A long rod with a large ball at the gathering end used to gather hot glass from the furnace, usually for the hot casting process. **Glory Hole** A heavily insulated cylinder, kept between 2100°F and 2300°F, which is used to reheat hot glass as it is being formed and manipulated in the Hot Shop. **Heat Shields** Protective devices that protect the glassblowing team from excessive heat coming from the glass as it is being worked and from other hot shop equipment, such as the glory holes. **Hot Shop** A workshop where molten glass is blown, cast or manipulated. **Jacks** Bladed tools used by glassblowers to shape molten glass. They come in various shapes and sizes to accomodate the work being made. **Laminate** Joining two pieces of glass by using heat or an adhesive. **Lampworking** Another term for flameworking. **Lip** The rim of a vessel. **Lip wrap** A thread of glass which is applied to the mouth of a vessel with a punty. **Marver** A large, flat surface on which hot glass is rolled when it is attached to a blowpipe or punty. **Melt** A term used loosely to describe the process of heating materials to make glass or to recycle glass. **Mold** A form used for creating specific shapes with molten glass. Hot glass can be poured or blown into a mold. **Optic Mold** An open mold with a textured interior into which a parison of hot glass is blown to create patterns in glass. **Paddle** A wooden board with a handle that can be used to shield the gaffer from excessive heat or to smooth or flatten hot glass. **Parison** A partially inflated gather of hot glass on the end of a blowpipe. **Pipe** Another name for blowpipe. A stainless steel or iron tube on which hot glass is gathered and through which the glass is blown. **Pipe Cooler** A device used to cool the shaft of the blowpipe after a gather. The pipe is placed across an open barrel of cool water; the water is pumped over the shaft of the pipe until it is cool enough to handle. **Pole turner** A member of the

glassblowing team who turns the blowpipe as hot glass is being blown or manipulated. **Pontil or Punty** A metal rod that is used to gather a small amount of hot glass, which is then transferred to the object or used to transfer the object making it possible to work the other end. **Pot** The container in the furnace in which batch is melted. Also known as a crucible. **Prunt** A small bit of hot glass applied as decoration. **Pyrometer** Special thermometer used to measure high temperatures in hot shop furnaces, annealers/kilns and other equipment. **Respirator** A face mask used to filter out harmful airborne particles. **Sandcast** Pouring hot glass into a mold made of casting sand. **Seeds** Very small air bubbles found in molten glass. **Shard** A small piece of colored glass that can be melted into a hot glass piece for decoration. **Shield** A paddle used to protect a gaffer or other member of the team from excessive heat. **Slump** Heating glass so that it softens and changes shape without becoming molten. **Stippling** Tapping the surface of a hot glass object several times with a tool to produce a decorative finish. **Thermal Shock** This occurs when glass experiences an extreme change in temperature, either a drastic increase or decrease. This will cause an inconsistency in the structure of the glass, creating instability and eventually cracking the glass. **Thread** Strand of hot glass that can be applied to a rotating parison to create a pattern or surface decoration. **Transfer** Attaching one piece of hot glass to another, usually using a punty and breaking it free from its original pipe or punty, enabling the glass artist to work the other end. **Tweezers** Tong-like tool used to grab or manipulate hot glass. **Wax** Beeswax, which is most commonly used, is applied to the blades of the jacks to prevent scratching or marking the surface of the hot glass. **Wrap** A strand of hot glass applied to a vessel. **Yoke** A metal stand on which blowers rest their pipes or punties while re-heating glass in the glory hole allowing for easy rotation.

Visual Art Glossary

2-D or two-dimensional An object that is flat—having height and width.**3-D or three-dimensional** An object that has height, width and depth and can be viewed from multiple points of view. **Abstract** A work of art exaggerating or simplifying real forms that may or may not be recognizable. **Archival** Art materials resistant to impacts of the environment (light, humidity) over time. **Balance** Equalization of elements in a work of art. **Color** What the eye sees when a wavelength of light is reflected from a surface. **Contrast** Opposite visual arts qualities placed side by side (e.g., light against dark, heavy against light, textured against smooth, etc.) to create visual interest. **Composition** The organization of parts or elements in a work of art. **Emphasis** Use of contrasts (color, size, shapes) to place greater attention on specific parts of a work of art. **Form** A three-dimensional object that has height, width and depth. **Installation** An art work especially arranged and constructed for an exhibit or space—sometimes forming an environment where variables of light, sound and perception of space are manipulated by the artist. **Line** A mark made with a tool or material across a surface. **Miniature Mixed Media Monumental Opaque** A material that absorbs or reflects light, not allowing light to pass through it. **Pattern** Repeating sequence of lines, shapes or colors. **Relief** A type of sculpture or surface in which forms project from a flat background. **Point of View Rhythm** Movement in art created through repetition of elements. **Scale** is a sculptural term for size; size in relationship to other objects. **Sculpture** A three-dimensional work of art. **Shape** A 2-dimensional enclosed space. **Space** The area above, below, around, and within a work of art. **Symmetrical/formal balance** A type of balance that results when both sides of an artwork are the same or mirror one another. **Technique** Methods of working with art materials to create artwork. **Texture** Real or implied tactile characteristics of a surface. **Translucent** A material that transmits light in diffused directions distorting its path. **Transparent** A material that transmits light in straight lines without distorting images. **Unity** Wholeness, all elements belonging together in a work of art. **Value** Lightness or darkness of an area of color or tone. **Variety** Diverse elements used together to create visual interest in a work of art. **Vessel** A container.

Science Glossary

Absorption Change of electromagnetic energy to other forms of energy as it moves through a medium. **Atom** The smallest particle of an element that has all of the element's chemical properties **Cone** The specialized cells in the retina of the eye that are sensitive to color, specifically red, green and blue. **Diffraction** A light beam bending and spreading out as it moves around an object or through a narrow opening(s). **Electromagnetic radiation** is energy carried through space in the form of waves. **Frequency** in any periodic motion (such as a wave) is the number of complete oscillation in a period of time. **Incident light** Light falling on or striking a surface. **Light** The portion of the electromagnetic spectrum (electromagnetic radiation with wavelengths from 400 to 700 nanometers) visible to the eye (stimulates the retina of the eye). **Molecule** A combination of atoms. **Optics** The science of light and it's interaction with sight. **Periodic table of the elements** Lists all of the different atoms found in nature. **Pigment** A colored material that absorbs certain colors and reflects or transmits other colors. **Prism** A piece of glass that has equal and parallel ends and sides with parallel edges that disperses white light into the full spectrum of colors. **Reflection** Rays of light bouncing off a surface. **Refraction** The bending of a light beam that occurs at the boundary between one material/medium or another. **Selective absorption** When one color of white light is reflected, while others are absorbed. **Spectrum** The band of colors making up white light. **White light** Light from the sun or an artificial source—it appears white but is composed of all of the colors of the spectrum.

References & Resources:

Hale, Meredith & et. al. 2006. *Science of Art: Glass in Everyday Life.*

Museum of Glass. [n.d.] *Museum of Glass.* [Online] Available: www.museumofglass.org.

Washington State History Museum on-line resources: Land, People, and Time: Guidelines for Teachers: Looking at Primary Sources.

Credits

Curriculum prepared by Meredith Essex, local art educator.

Images

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Joe Feddersen (American, born 1953)
Wilderness, 2005
Blown glass, 19 ¼ x 19 ¼ x 13 ¼ inches
Museum of Glass, gift of the artist

Page 11

Sonja Blomdahl (American, born 1952)
Sienna/Blue, 2003
Blown glass
Museum of Glass, gift of the artist

Amber Hauch (American, born 1969)
Shoe, 2004
Hot sculpted glass
Museum of Glass, gift of the artists

Dante Marioni (American, born 1964)
Yellow and Black Vessel, 2002
Blown glass, 15 ½ x 8 x 7 inches
Museum of Glass, gift of the artist

Oiva Toikka (Finnish, born 1931)
Tristan and Isolde, 2004
Blown glass
Museum of Glass, gift of the artist and iittala, Inc.

Karen Willenbrink-Johnsen (American, born 1960)
The Juggler, 2003
Hot-sculpted glass
Museum of Glass, gift of the artist

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