radical lace & subversive knitting

Museum of Arts & Design

TEACHER RESOURCE PACKET

January 25—June 17, 2007

The Crafted Classroom
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Dear Educator,

We are delighted that you have scheduled a visit to ***Radical Lace & Subversive Knitting***. When you and your students visit the Museum of Arts and Design, you will be given an informative tour of the exhibition with a museum educator, followed by an inspiring hands-on project, which students can then take home with them. To make your museum experience more enriching and meaningful, we strongly encourage you to use this packet as a resource and work with your students in the classroom before and after your museum visit.

This packet includes topics for discussion and activities intended to introduce the key themes and concepts of the exhibition. Writing, storytelling and art projects have been suggested so that you can explore ideas about the exhibition in ways that relate directly to students' lives and experiences. Please feel free to adapt and build on these materials and to use this packet in any way that you wish.

We look forward to welcoming you and your students to the Museum of Arts and Design.

Sincerely,

Aliza Boyer
Senior Manager of School, Youth & Family Programs

Lisa Litwin
Education Department Assistant

Rachel Farmer and
Zack Davis
Artist Educators

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Museum of Arts & Design

The Museum of Arts and Design has been functioning as an international resource center for craft, arts and design since 1956. Through its collections, exhibitions, programs and publications, the Museum serves as a forum for critical debate concerning the nature of craftsmanship and the engagement with the process that links materials, techniques, forms, patterns and concepts in all creative works.

How does a museum work?

- **Administration:** The team led by the Director of the Museum determines the programs, plans and philosophy of the Museum. It also raises funds to realize the Museum's goals and works directly with the Board of Governors, which guides the Museum's functions.

- **Education:** This team provides the interactive interpretation of the objects on view through the educational programs designed for children, adults and families who visit the Museum. This team also creates and disperses written educational materials on current and upcoming exhibitions and provides tours for diverse audiences.

- **Curatorial:** This is the team, led by the Chief Curator, that works together to decide which exhibits will be shown, how they will look, what artwork is to be included, and how they are to be interpreted.

- **Registration:** Led by the Registrar, this team arranges the safe handling of art to be placed in an exhibition and maintains the permanent collections acquired by a museum.

- **Development:** This team collects the financial resources for the Museum from independent donors, foundations and corporations.

- **Public Relations/Marketing:** This team publicizes the Museum's exhibitions and programming with advertisements and media exposure.

- **The Store/Retail:** This team is responsible for maintaining, protecting and selling the merchandise in the Museum's store.

- **Facility Maintenance:** This is the team that allows the day-to-day operations of a museum to continue: from the lights being turned on, to the safety of all who enter the building.

- **Security Guards:** This is the team most often seen in a museum, because its main task is to protect the artwork from harm so that in the future people will be able to see the same objects as seen in a museum today. They also are helpful to visitors who have a variety of questions.

Museums are places where we can learn about the past, present, and future of the world around us. The diversity of knowledge is endless when the habit of museum exploration is formed at an early age. We look forward to welcoming your group into our galleries.

Helpful Hints for your Museum Visit

While visiting the exhibition try to use all your senses. Notice the way the pieces are displayed. *Are there any specific groupings of pieces you can distinguish? If you enjoy looking at one piece more than others can you explain why?*

Here are some questions and suggestions to think about as you move around the exhibition:

I. *What can be objectively observed?*
   a. What is the physical description? Measurement, weight, materials used, articulation of materials…
   b. What iconography, if any, is used? Designs, words, diagrams…
   c. What are the object's formal design characteristics? Lines, shapes, forms, color, texture…

II. *What would it be like to interact with this piece of art? How would you handle, lift, display it?*
   a. How would the piece of art feel, move, and sound?
   b. What does the piece do? Does the piece have a function? How would the figures move if they were alive?
   c. What is our emotional response to this beaded figure? Fear, joy, indifference, curiosity, revulsion, excitement…

III. *What is in the mind of the artist? What are the viewers thinking and feeling?* Use creative imagining and free association.
   a. Review all of the above information and consider what was going on in the world when the work was produced to develop possible interpretations of the piece. (i.e. theories and hypotheses)
   b. *Do the figures tell a story? Does the piece have underlying political or social meaning?* (i.e. understanding and visual thinking)
   c. Develop a program to investigate the questions posed by the material evidence. (i.e. researching)

"I try, when I go to museums, to do two things. One, to appreciate what I'm looking at, just to see it, but then to isolate a few pieces that I really look at in detail. I study and I draw not with any purpose in mind. I mean, I don't go looking for specific things. I just try to be open-minded and keep my eyes open. It's interesting that every time I go back to the same place, I see something different." Arline M. Fisch (1931-) Brooklyn, New York

Radical Lace & Subversive Knitting

January 25, 2007 through June 17, 2007

Radical Lace & Subversive Knitting explores the phenomenal rise to prominence of knitting, crocheting and lace making in the work of contemporary artists from around the world. Blow torches, fiber optics, digital technology, shredded currency, video, chocolate, and even knitting needles the size of telephone poles are hallmarks in the work of these artists, who have reinvented traditional handcrafts through their introduction of new materials and unorthodox techniques.

Radical Lace & Subversive Knitting showcases approximately 40 works, ranging from obsessive miniatures to architectural interventions, video installations, and performance and participatory pieces—nearly half of which were created especially for the exhibition.

"These are not your grandmother's crocheted doilies and knitted legwarmers," said Chief Curator David McFadden. "The traditions that have defined both knitting and lace making for centuries are suspended in this exhibition. Each piece bears a political or personal message, invites public participation, and encourages the viewer to reconsider how fiber functions on a tangible, spiritual and aesthetic level."

The works selected for *Radical Lace & Subversive Knitting* do not readily accept neat classification within the traditional triad of art, craft and design, nor do they fulfill stereotypical expectations of either knitting or lace making. The 27 featured artists are both male and female, of various ages and nationalities. What brings them together is a vision that uses fiber to explore line and space, marrying traditional methods, such as knitting needles and crochet hooks, with new technologies and materials that include rubber, lead, glass, industrial wire shelving and found objects. For many of these artists, *Radical Lace & Subversive Knitting* will be their first major New York presentation.

Radical Lace & Subversive Knitting reveals affinities in content and structure among the works on view, which are subdivided into six thematic groupings:

- **Corporeal Constructions** explores works that reference the human body, both indirectly through imagery or content and directly through costume and dress.
- **Matters of Scale** examines the way in which size and scale can influence the viewer's understanding of the work.
- **Light Constructions** features works that explore the transmission of light as an integral element in the work, or consider "lightness" in materials and visual effects.
- **Interconnections** highlights the work of artists who extend their engagement with materials and process to the public, either through performance or participatory art making.
- **Creative Deconstructions** presents the work of artists who use subtractive rather than additive processes to arrive at their final work.
- **Beauty of Complexity** presents the work of artists who use fiber in ways that resonate with the connections between making art and writing texts.

Knitting
Knitting is the act of forming a fabric by looping a continuous fiber.
It is one of several techniques that can be used to turn thread into cloth.

History of Knitting

The exact geographical origin cannot be specified but the craft is believed to have been developed B.C. The oldest remnants of seemingly knitted pieces are socks. These early pieces were produced by a technique similar to knitting called Nålebinding.

The first references to true knitting in Europe were in the early 14th century. The purl stitch was unknown at this time and it was necessary to knit in the round and then cut it open. The first reference to the purl stitch dates from the mid-16th century.

Men were the first to knit as an occupation. The first knitting trade guild was started in Paris in 1527, establishing the occupation as male dominated for centuries to come.[1] With the invention of the knitting machine, knitting by hand became a useful but not an essential craft, and its practitioners were increasingly female.

With the industrial revolution most wool spinning and cloth manufacture was done in factories. More women were employed to operate the machinery, rather than produce their home spun and knitted items.

During WWII, wool was in short supply. The British wartime government encouraged women to unpick any old, unwearable, woolen items in order to reuse the wool. They also issued knitting patterns for people to make items for the Army and Navy to wear during the winter.

After the war years, knitting had a huge boost as greater colors and styles of yarn were introduced. Many thousand of patterns fed a hungry market for fashionable designs in bright colors. Girls were taught to knit in schools, as it was thought to be a useful skill not just a hobby.

The popularity of knitting slowed in the 1980's. The craft was seen as old fashion and children were rarely taught to knit in schools. This was partly due to the increased availability and low cost of machine knitted items that meant that consumers could have a sweater at the same cost as purchasing the wool and pattern themselves or often for far less.

The 21st century has seen a knitting revival. This is part due to the internet phenomena of blogging and internet groups and lists, fueling the development of an international knitting community. Manufacturers and designers have looked for new ways to stimulate interest in knitting. They have created novelty yarns. There has also been resurgence in popularity of natural-fiber yarns, replacing acrylic yarns which have long dominated the market, and also aided in the decline in the popularity of knitting.
(From http://en.wikipedia.org/wiki/History_of_knitting)

[1] www.en.wikipedia.org/wiki/knitting, p.2.

Lace

What makes lace so different from other textiles? Its most striking characteristic is that it is full of holes. These holes are formed as the lace is made and not cut out afterwards. For this exhibition the definition of lace is a structure made out of some sort of fiber that allows light to pass through it.

History of Lace

"Of many Arts, one surpasses all. For the maiden seated at her work flashes the smooth balls and thousand threads into the circle,…and from this, her amusement, makes as much profit as a man earns by the sweat of his brow, and no maiden ever complains, at even, of the length of the day. The issue is a fine web, which feeds the pride of the whole globe; which surrounds with its fine border cloaks and tuckers, and shows grandly round the throats and hands of Kings." – Jacob Van Eyck, 1651.

The birthplace of lace making is generally recognized as Flanders and Italy. Lace making is an ancient craft but true lace was used very little until the time of Elizabeth. A true lace is created when a thread is looped, twisted or braided to other threads independently from a backing fiber. All lace was handmade and very, very expensive. As an example, to manage to buy enough lace for a large ruff a man might have to sell a few acres of land to raise enough money. Lace was treasured and passed down in families. It was a symbol of wealth and status.

Lace was developed from whitework where threads of the ground were either pulled out or cut away from between the embroidered parts. The embroidery became ever finer until hardly anything was left of the ground fabric.

One of the reasons that lace became popular was due to fashion. Lace was designed to replace embroidery in a manner that could with ease transform dresses to follow the different styles of fashion. Unlike needlepoint, lace could be sewn and unsown from one material to be replaced on another. The constant drive to make clothing more attractive is responsible for the creation of the finest and most costly trimming now call classic lace. By the time of Charles I lace was used extravagantly for both costume and interior decorating. By the mid-17th century, lace making had become an established industry.

With the advent of the industrial revolution and the invention of machines to make lace, the price and prestige of lace dropped. By the 20th century, lace has lost its status and is mainly used to make and decorate lingerie.

Today both knitting and lace take on new meanings. They are not necessarily functional objects anymore and not necessarily just a female activity.

Pre-Visit
Classroom Activities

Pre-Visit Activity 1: Finger Knitting
Suggested level: All ages

Objectives:

a) Introduce students to fiber arts.
b) Introduce students to finger knitting. Finger knitting is knitting with one's own fingers in place of traditional knitting needles.

Vocabulary:

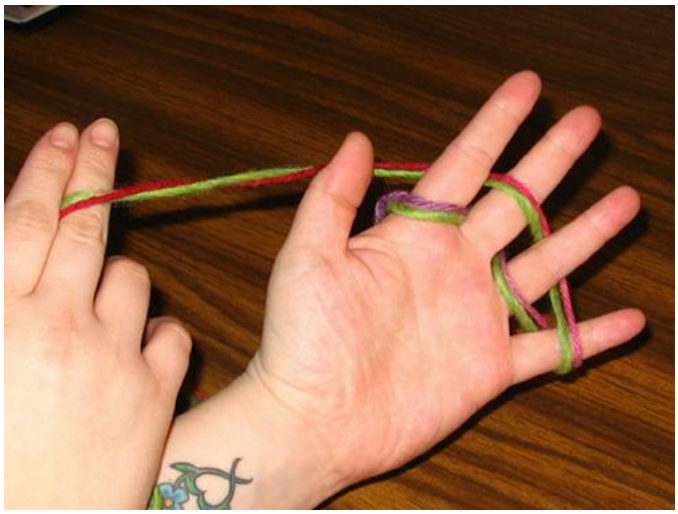
- Casting
- Stitches

Materials:

- Yarn (preferably a thick yarn)
- Scissors

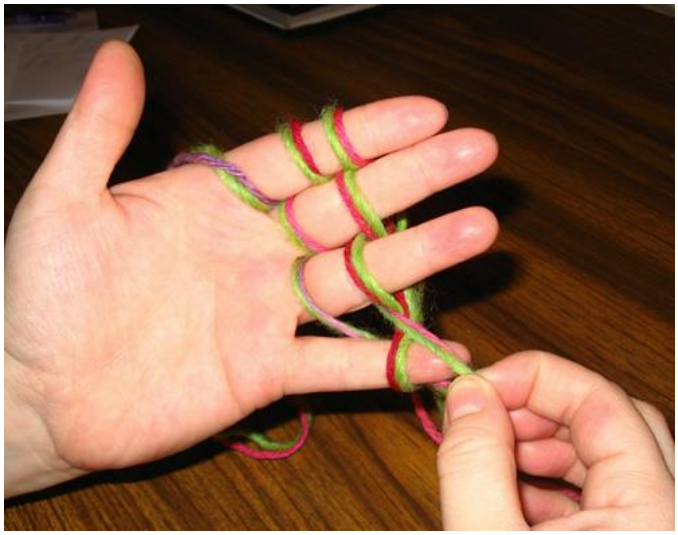
Finger Knitting Step by Step Instructions (These easy to follow instructions are by Janelle Masters from the www.knitty.com website):

Casting On



Begin with your left hand facing you (assuming you are right handed. For lefties, begin with the right hand facing you). The tail of your yarn(s) should be placed in the area between your left thumb and index finger. Begin casting on by wrapping the working yarn over the index finger, behind the middle finger, over the ring finger, etc. Once you wrap around the pinkie, continue back the other direction until your reach the index finger once again. Go around the index finger a second time and wrap all fingers in the same manner slightly above the wraps from the first pass. Try to maintain loose wraps. You not only need to be able to work the stitches, you also don't want your lovely fingers to turn blue.

The First Row

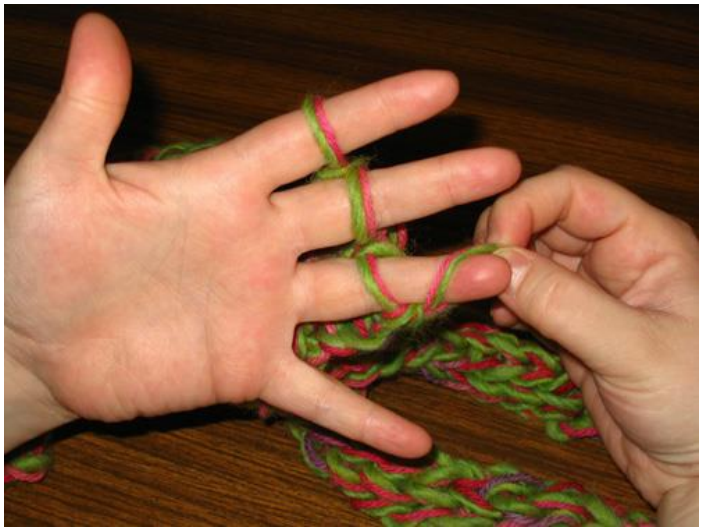


Beginning at the pinkie, lift the wrapped yarn on the bottom (nearest your palm) up and over the tip of the finger, keeping the top wrap on the finger as you pass the lower wrap over and off. *Remember that in these photos, I'm using two strands held together as one.* Continue this process along the hand until your reach the index finger. Be careful as you lift the stitch on the index finger since the bottom wrap is actually the tail of your yarn. (Just don't let it get away from you!)

All Following Rows

For the next row, and every other row, begin by once again wrapping the working yarn around all four fingers as in step one. Next, each lower stitch is passed over the upper stitch and lifted off the finger as in step two. This two-step process continues until the work is the desired length. When making scarves, I like to knit about eight to ten feet of finger knitting and double-up the strips around the neck. Should you need to put down your finger knitting sometime during construction, I recommend sliding the working stitches onto a ballpoint pen and hooking them under the paper-clippie thing at the top. (This is a needle-free area, remember?) When ready to begin again, place the working stitches back onto the fingers with the stockinette side of the work facing the back of your hand.

Binding Off



Once the chosen length is reached, the knitter must bind off the working stitches. On this last row, do not wrap the fingers. Each finger should have only one loop on it. Lift off the loop on the pinkie finger and place it onto the ring finger. On the ring finger, lift the bottom loop up and over the top loop and off the finger. Next, place the remaining loop from the ring finger onto the middle finger and repeat the lifting off/moving over step until one loop remains on the index finger. To finish, simply cut a tail and pass it through the remaining loop, pulling it tight.

These easy to follow instructions by Janelle Masters from the www.knitty.com website.

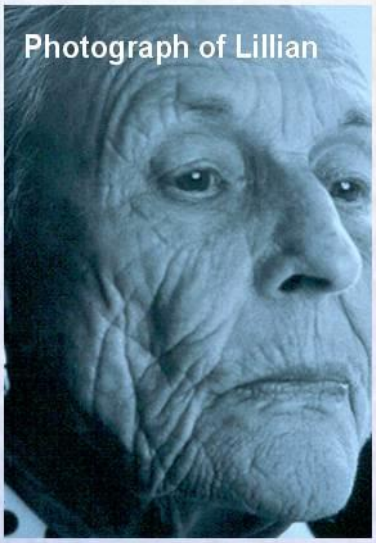
Featured Works

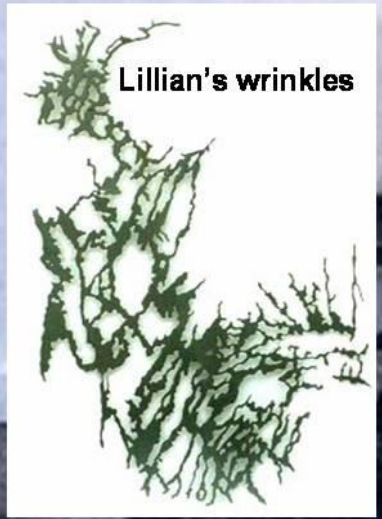
Corporeal Constructions

Barbara Zucker
Lillian's Face Flowing, 2005
Rubber
Dimensions variable
Collection of the artist

Artist process: the artist uses facial images of older women, herself, friends, or well-known women whom she admires and creates striking sculptures. She searches for a striking pattern produced by the wrinkles, which she enlarges and manipulates and this becomes the template for her sculpture.

- ***What natural form does this remind you of?***
- ***What do you think this would feel like?***
- ***How would you feel if you were part of this sculpture?***
- ***How does the color affect you? Why do you think the artist chose this color?***
- ***Where would you likely see this sculpture?***
- ***Why do you think the artist used this material to create this sculpture?***
- ***How does this sculpture relate to lace as you know it? Do you see any distinct pattern?***


Photograph of Lillian


Lillian's wrinkles

Liz Collins
Illuminated Veins, 2006
Reflective and silk blended yarn
Dimensions variable
Collection of the artist

This evening gown is based on a classic 1950s silhouette and combines silk chiffon with knitted "veins" of reflective yarn that extend out from the dress and connect to and interact with parts of the museum architecture.

Artist process: Collins' signature technique is called "knit grafting." She applies this technique in her work by knitting multiple rows of narrow cords and, once every several rows, attaching a piece of non-knit fabric to the knitting structure so that they "fuse" together.

- Where do you think the artist got the inspiration for this dress?
- What animal do you think could have created this garment?
- Is this something you would want to wear? Why or why not?
- How would it feel? How would it make you feel?
- How does this garment fit into the definition of knitting and/or lace?

Matters of Scale

Althea Merback
Ancient Greek Pullover, 2005
Silk thread
2 ½ x 1 ½ in.
Kathleen S. Browning Miniatures Collection, Kentucky Gateway Museum Center, Maysville

Ancient Greek Gloves, 2005

Artist Process: Althea Merback knits at one-twelfth scale by making knitting needles out of stainless steel medical wire used for inserting I.V.'s. She buys the medical wire in 60in lengths and cuts them to the required length and then grinds down and polishes the end to a dull point.

- Where do you think the artist got the inspiration for these objects?
- What objects do they remind you of? Why?
- What are the characteristics of these objects? Do you see any specific patterns?
- Are these objects you would like to wear? Why or why not?

Dave Cole
Knit Lead Teddy Bear, 2006
Lead ribbon, hand-cut and knitted over armature of lead wool
6 x 5 ½ x 4 ½ in.
Courtesy Judi Rotenberg Gallery, Boston

This toy is not only dangerous but impossible for a child to lift.

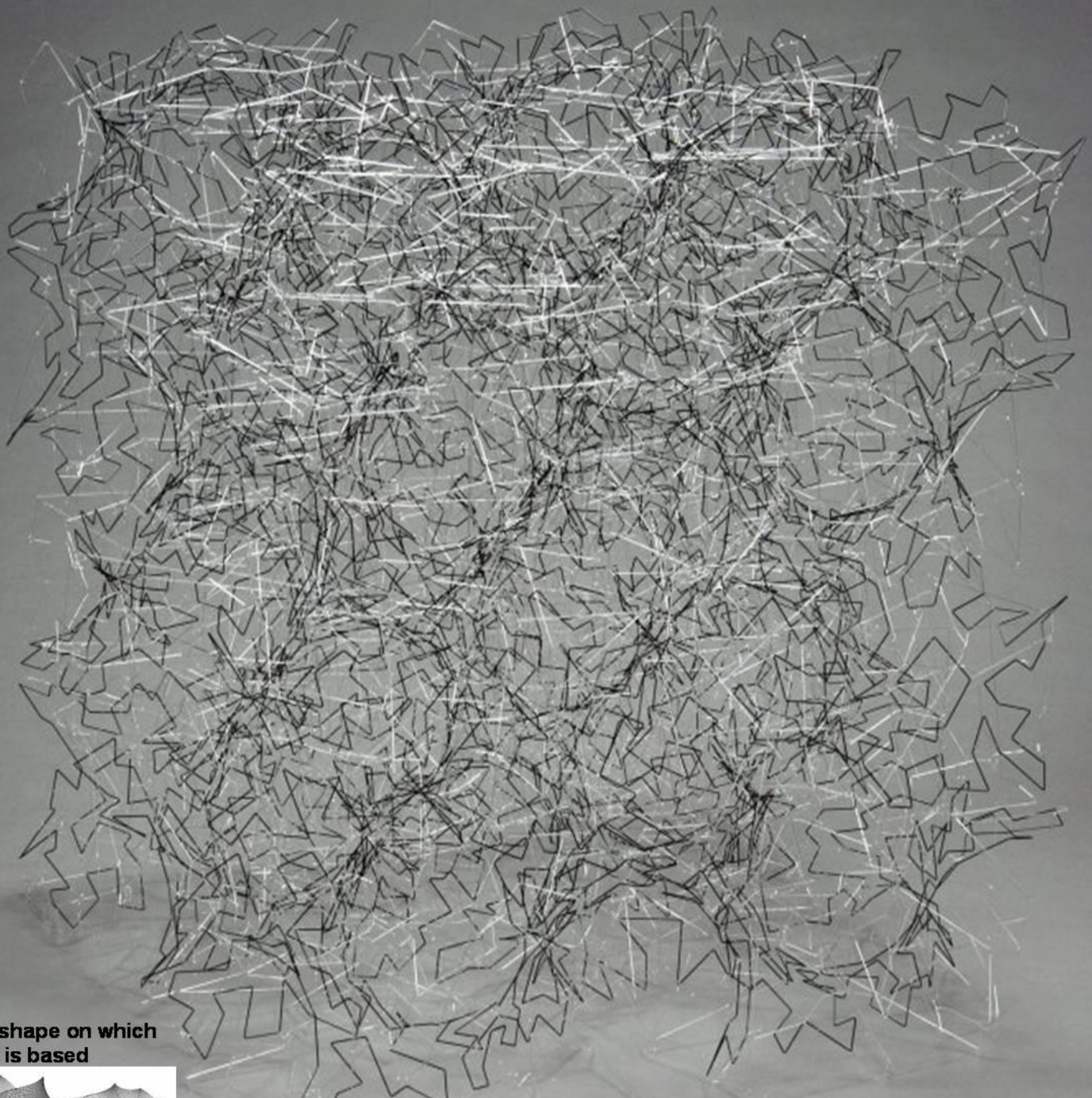
The artist likes to play with his audiences expectation of scale and materials. He uses the complexity of his structures on these scales to engage the viewer. The actual process of making the objects is also important to the artist who sees knitting as "obsessive, repetitive, grinding work," but also as a "trope for work, metaphor for every kind of production."

- What do you think this teddy bear would feel like to touch? To hold?
- How does this teddy bear differ from your teddy bear or others you have seen or held?
- Would you want this to be your teddy bear? Why or why not?
- Would this teddy bear be light or heavy? What does the material this object is made of remind you of?
- What message is the artist conveying by crafting this object out of lead?

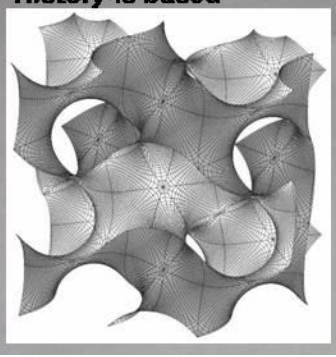
Light Constructions

Bennett Battaile
History, 2005
Clear and black flameworked glass
37 x 36 x 36 in.
Collection of the artist

Artist's process: Battaile applies mathematical concepts to structural form to make lace-like glass sculptures. These complex lattices composed of thin glass rods are visualizations of math problems that interest him. "I find a visual idea in math, I see if I can picture it, then I try to bring in multiple ideas and mix them together. Eventually I will come up with an idea which I can't picture, which makes it interesting, and I try to make a sculpture out of it." The initial inspiration for *History* was a gyroid shape (see inset), composed of a series of connected saddle-shaped curves, which he set out to make using a formula known as a Hilbert space-filling curve.



Gyroid shape on which *History* is based



- What does this object remind you of?
- What do you think of the material the artist used to complete this object?
- Where would you put this object in your home?
- What do you think this object would feel like to touch? Hard or soft? Rough or smooth?
- How much do you think this piece weighs?
- What do you think of the way the artist has used light?
- How does this piece relate to traditional lace?

Henk Wolvers
Lines I, 2006
Porcelain
Each: 39 1/2 x 9 1/2 in.
Collection of the artist

Artist's process:
For this exhibition Wolvers used a strengthened porcelain slip and a painter's brush to slowly drip the fluid clay onto plaster boards to form two large rectangular panels. When fired in the kiln, the "drawings" shrank and hardened, creating a surface texture and composition of overlapping thick and thin lines that invite comparisons to Jackson Pollock's Abstract Expressionist "drip" paintings. The resulting porcelain lace panels are mounted a few inches from the gallery walls, supported only by two wall-mounted nails, making them look as if they are suspended in space. The delicate openings invite a play of light, now more complex, which interlaces within, around, and through the porcelain, while elusive shadows cast on the walls surround and underscore the glowing form. The artist says, "Porcelain is very difficult to work with. It is not possible to make all the forms you want with porcelain because there are certain restrictions imposed by the medium. It is nice to go beyond the edges of those limitations."

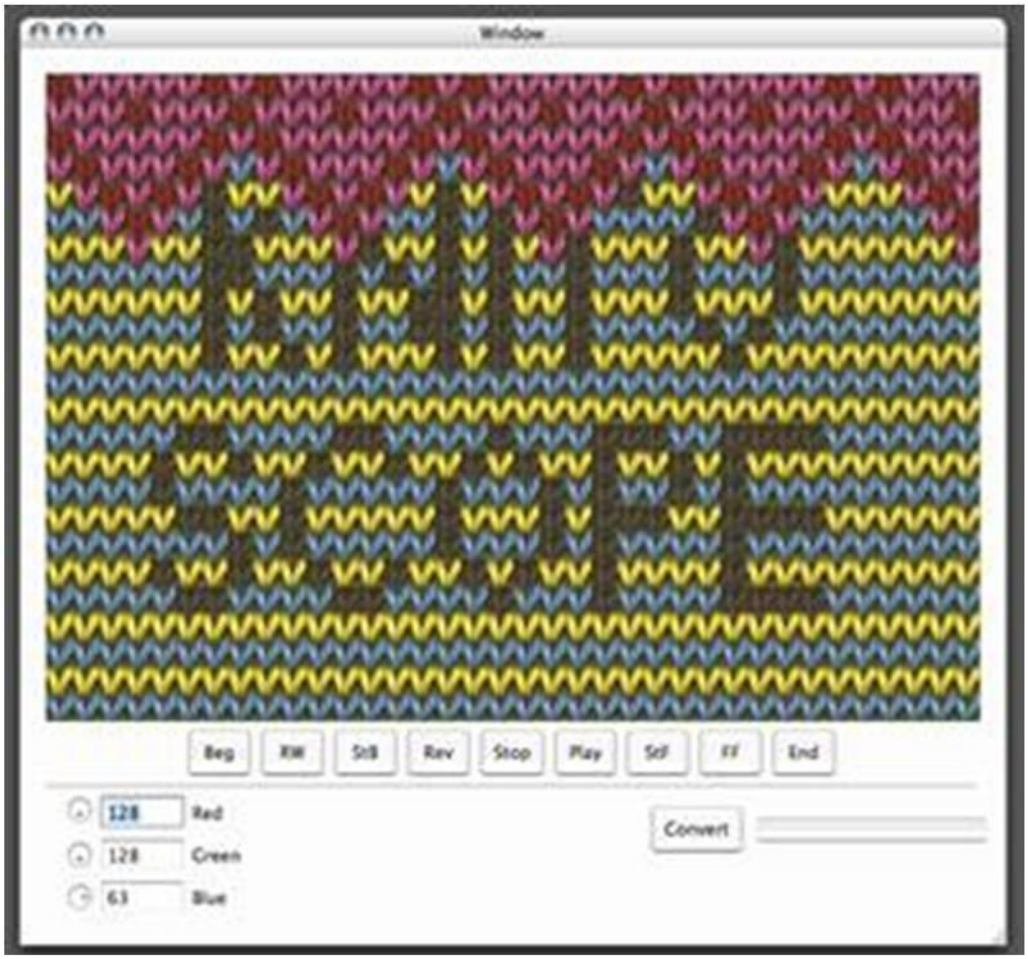
- What do you think the artist's inspiration was for this piece?
- Does the pattern remind you of anything in nature?
- How would this feel to touch? Would it be light or heavy?
- What does the use of the color white say to you?
- How do you think this work would work with light?
- What room would you use these panels in your home?
- What edible material does this remind you of?
- What could you use this for?
- How does this object relate to traditional forms of lace? How does it differ?

Interconnections

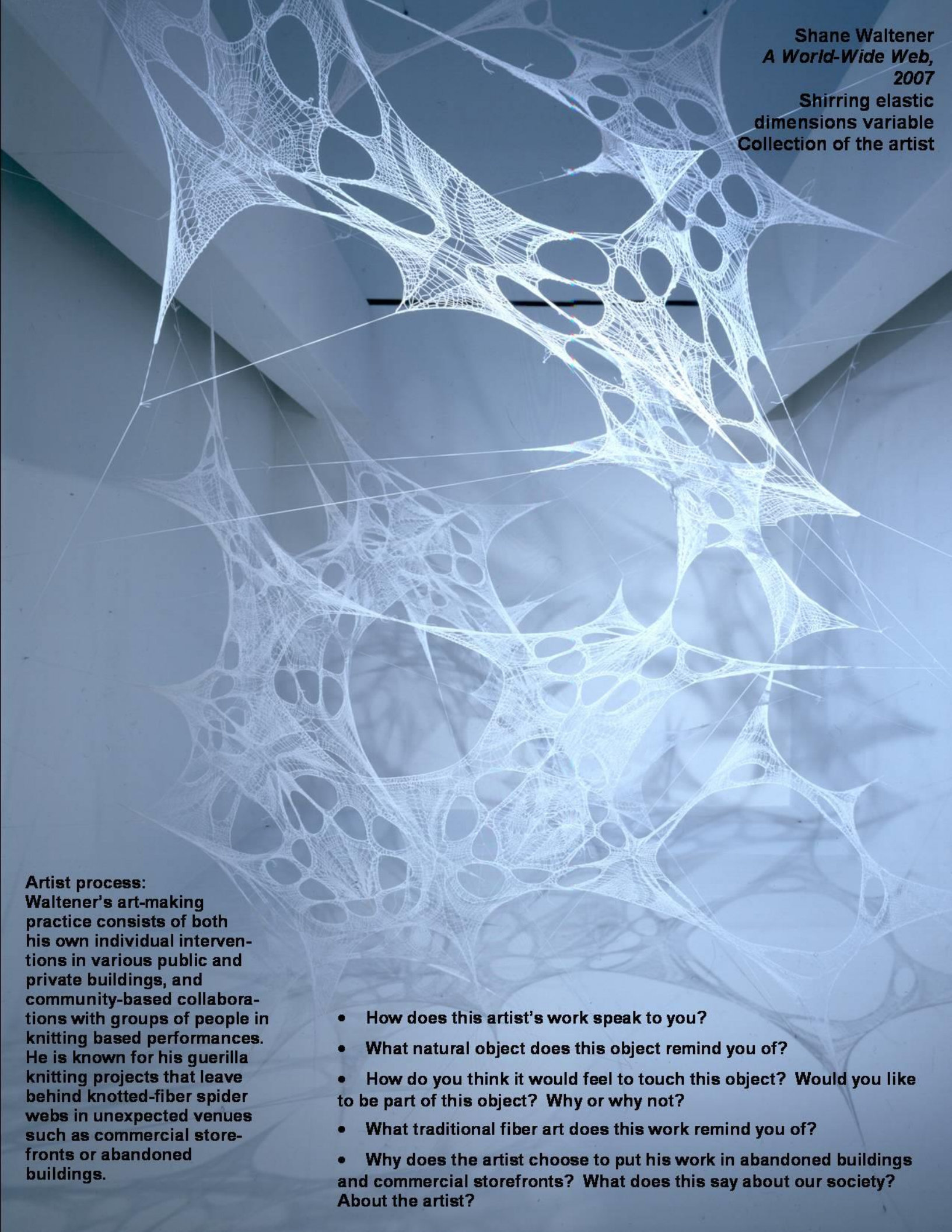
Cat Mazza
Knitoscope Screen Shot II, 2006
Knitoscope animation software with digital video feed.

Mazza created this program called knitPro, which translates a still or moving image directly into patterns for knitting, crocheting or needlework. The software can be used without cost to anyone.

The decision to make knitPro available to the public for free underscores the artist's commitment to communal goals and ideals.



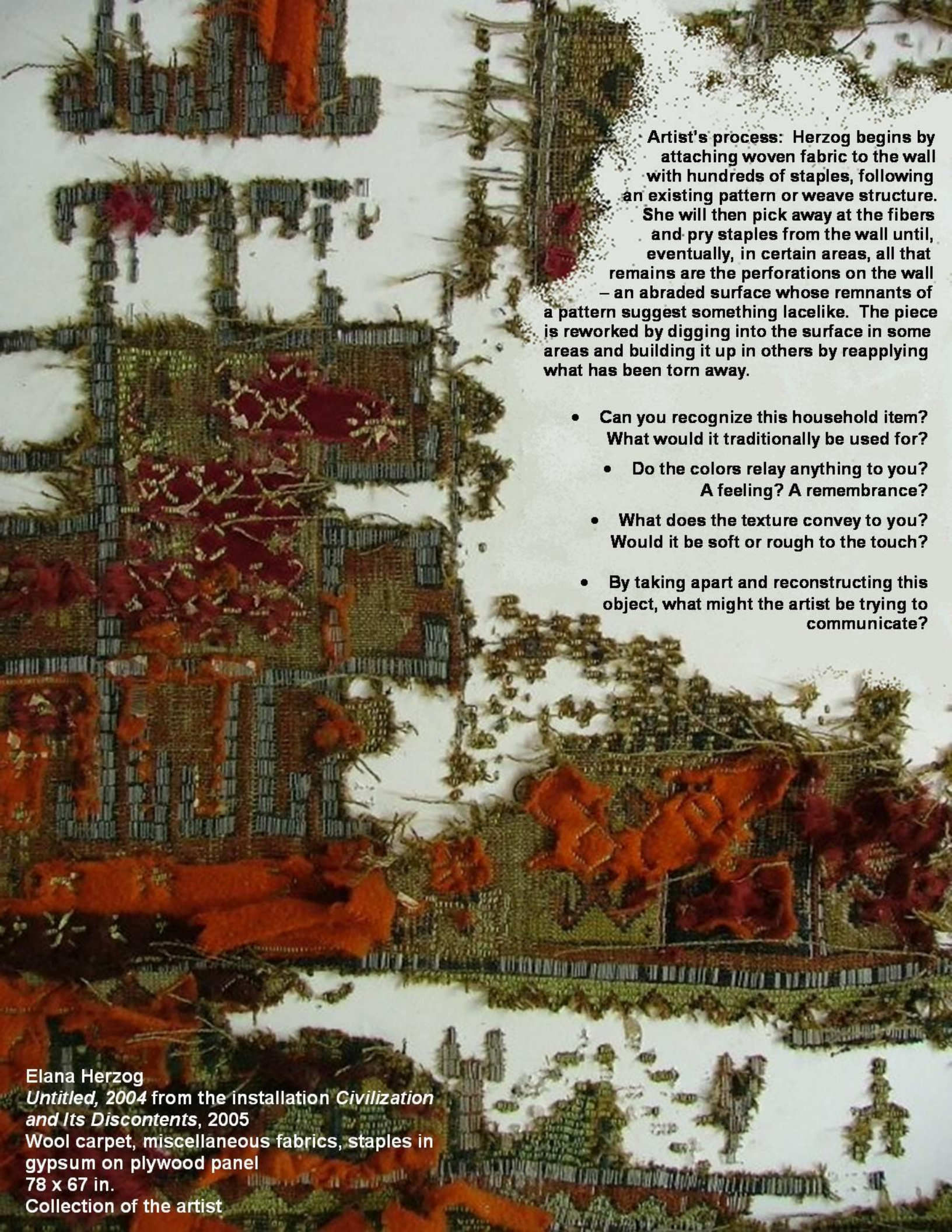
- What do you think of this software program?
- Why do you think the artist chose to give the public free access to this computer program?
- Is this something you would like to use? How would you use it?
- Do you have any images you would like to translate into a knit pattern? Why?



Shane Waltener
A World-Wide Web, 2007
Shirring elastic
dimensions variable
Collection of the artist

Artist process:
Waltener's art-making practice consists of both his own individual interventions in various public and private buildings, and community-based collaborations with groups of people in knitting based performances. He is known for his guerilla knitting projects that leave behind knotted-fiber spider webs in unexpected venues such as commercial storefronts or abandoned buildings.

- How does this artist's work speak to you?
- What natural object does this object remind you of?
- How do you think it would feel to touch this object? Would you like to be part of this object? Why or why not?
- What traditional fiber art does this work remind you of?
- Why does the artist choose to put his work in abandoned buildings and commercial storefronts? What does this say about our society? About the artist?



Artist's process: Herzog begins by attaching woven fabric to the wall with hundreds of staples, following an existing pattern or weave structure. She will then pick away at the fibers and pry staples from the wall until, eventually, in certain areas, all that remains are the perforations on the wall – an abraded surface whose remnants of a pattern suggest something lacelike. The piece is reworked by digging into the surface in some areas and building it up in others by reapplying what has been torn away.

- Can you recognize this household item? What would it traditionally be used for?
- Do the colors relay anything to you? A feeling? A remembrance?
- What does the texture convey to you? Would it be soft or rough to the touch?
- By taking apart and reconstructing this object, what might the artist be trying to communicate?

Elana Herzog
Untitled, 2004 from the installation *Civilization and Its Discontents*, 2005
Wool carpet, miscellaneous fabrics, staples in gypsum on plywood panel
78 x 67 in.
Collection of the artist

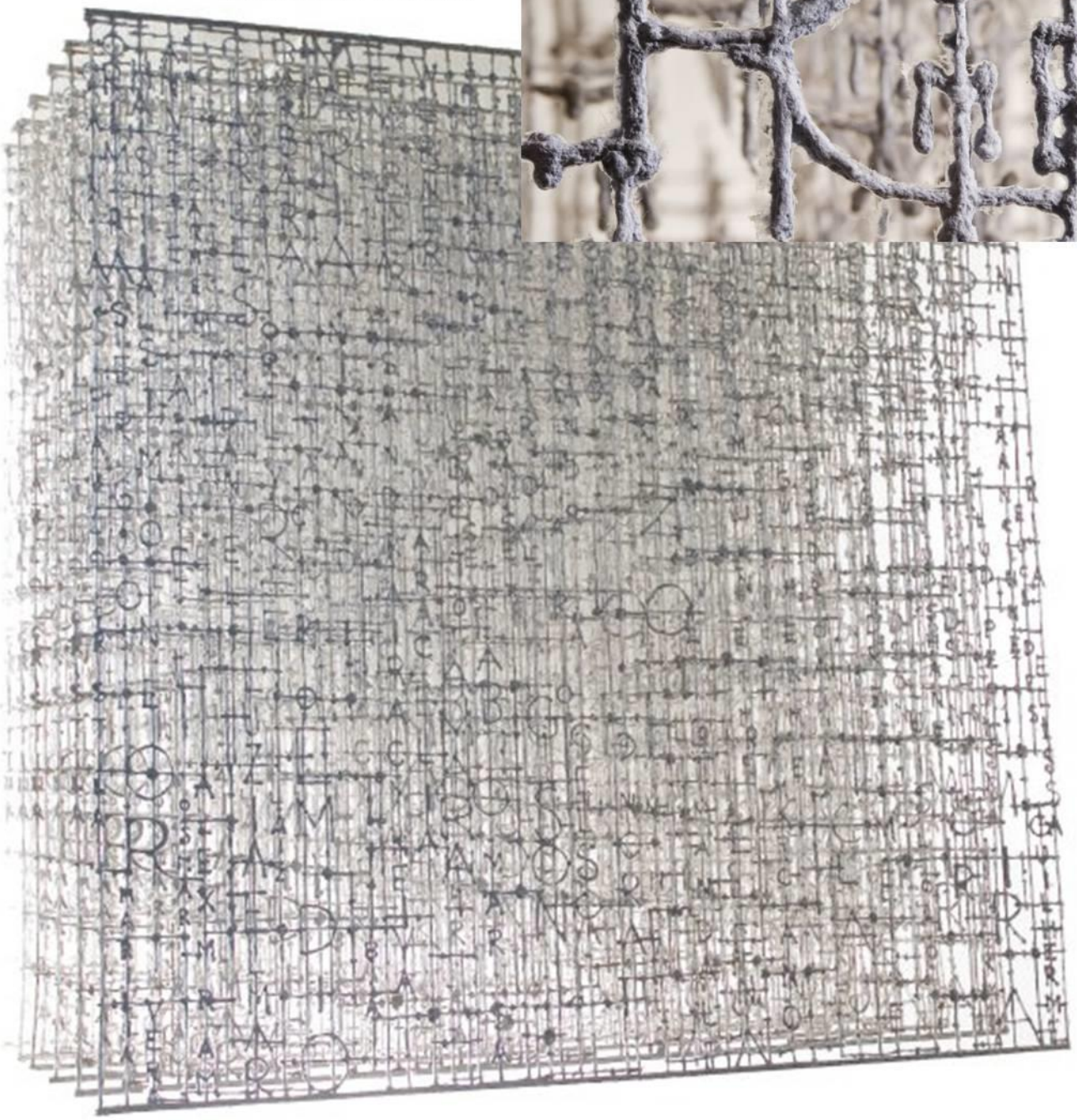
Artist's process: Lane uses found objects, often of a very industrial nature, and trans forms them into lace fantasies. She has developed a technique of torch cutting metal and uses this proces to create lacey garden spades, wheelbarrows, dumpsters and steel I-beams. What is ironic in her work is lace is primarily considered a feminine accessory to dress. Her lace sculptures are very mas culine forms completely penetrated by the feminine – a role reversal that requires viewers to rethink stereotypes and conventional expectations.

- What does this installation remind you of?
- Is this something you would want in your home? Why or why not?
- What do the colors say to you? Why do you think the artist has chosen them?
- How would these items feel to touch? Do you think the would be smooth or rough? Hot or cold?
- Are the items the artist chose to work in items you could use? Why or why not?
- What do you think of the way the artist uses lace to transform her work?

Cal Lane
Untitled, 2007
Dirt, tomato paste, plasma-cut wheelbarrow and shovels, flame-cut I beams
Dimension variable
Courtesy Foley Gallery, NY

Beauty of Complexity

Hilal Sami Hilal
left: *Untitled* (detail), 2005
below: *Untitled*, 2005
Cotton fiber, pigments
67 x 67 x 39 in.
Collection of the artist



Artist process: Hilal works with cotton fiber and metallic powders to create filmy lace-like structures that range in size from small to installation sized. "The art makes use of two opposite procedures – construction (paper) and deconstruction (copper) – to obtain the same outcome: fragility, transparency, emptiness." Many of his works incorporate text, where language becomes abstract with the real words and letters turned into decorative symbols. In this work for the exhibition, the book has become a series of veils or screens, with a series of letters repeated in three dimensions.

- **What letters do you see? Can you make out any words?**
- **How does this work make you feel? How do you think you would feel if you were a part of this work?**
- **How would this object feel to touch? Would it be hot or cold? Rough or smooth?**
- **What do you imagine this object would smell like? Why?**
- **Why do you think the artist chose this color for the object?**
- **How does this work relate to lace?**

Edward Mayer
Drawing In, (installation view) 2006
Steel shelving, found objects, vinyl tape, wood, plastic zip ties
Dimensions variable
Collection of artist

Artist process: Mayer's work is made from found materials such as commercial white wire shelving, tubing, metal fences and tree limbs all covered with surveyors tape to render them white and neutral. He creates large scale architectural installations that literally and figuratively fill space with lace-like structures.

• How does this work make you feel? Do you think your feelings would change if you walked within the work? Why or Why not?

•Why do you think the artist chose the color white? If the color changed would this change your view of the work? Your feelings from/of the work?

•How do you think this work would feel to touch? Would it be hot or cold? Why?

•How does this artist work relate to lace?

Post-Visit
Classroom Activities

Activity 1: **Small-scale/Large-scale Line Sculpture**
Suggested Level: Grades K-2
Time: 1-2 sessions

Objectives:

- Students will understand that sculptures can be both large-scale and small-scale.
- Students will understand that paper can be changed in a variety of ways to make three-dimensional sculpture.
- Students will understand that materials such as paper can be connected in a variety of ways to create a sculpture.
- Students will understand that sculptures can be composed using a wide variety of lines.
- Students will be able to create both an individual small-scale sculpture and a group large-scale sculpture and understand that scale makes a difference both in the art-making process and in the viewing of the sculpture.

Materials:

For large group sculpture --

- Paper cut into wide strips
- Large cardboard base
- Scissors
- Glue

For small individual sculptures --

- Paper cut into very thin strips
- Small cardboard (or thick paper) bases
- Scissors
- Glue

Vocabulary:

- Sculpture
- Three-dimensional
- Large-scale
- Small-scale
- Miniature
- Fold
- Bend
- Curl
- Twist
- Crumple

Part One:

Review your visit to the Museum.

- *Did you see any art objects that were made out of lines? What kinds of lines did you see?*
- *What materials were these lines made out of?*
- *What was the largest work of art that you saw? What was it made out of and how was it connected together? How did it make you feel to be next to it?*
- *What was the smallest work of art that you saw? What was it made out of and how was it connected together? How did it make you feel to be next to it?*

Part Two:

Introduce materials they will be using to create a sculpture: paper

- *How can we change this paper to make it three-dimensional? (fold, bend, curl, twist, crumple)*
- *How can the paper be joined together without the use of glue or staples?*

Part Three:

Introduce two concurrent projects:

1. Create a small-scale individual sculpture using very thin paper strips.
2. Create a large-scale group sculpture using wide paper strips (a few students at a time can be pulled over to work on this – with eventually all students having a turn to add to the sculpture).

Alternative (time permitting):

- Another option would be to break the art making into two sessions. One session could be focused on creating a small-scale sculpture. The following session could be focused on creating a large-scale group sculpture.
- Referring back to knitting -- the process of using a single fiber (or line) to create a structure.
- Challenge students (in either the individual or group sculpture), to first connect all of their paper strips into one long line, then create their sculpture using this single line. Or they could first change their individual paper strips (by folding, curling, twisting, etc.) then connect them into one long line, turning this into a collaborative sculpture.
- The cardboard bases can be used to attached sculptures (or parts of the sculptures) to. Another option—space permitted—is to connect sculptures to the wall or floor. (Watch the shadows as they develop!)
- Students could then compare and contrast their experience working individually and as a group, and discuss the resulting sculptures made by using several shorter lines versus one long line.

Part Four:

Place all sculptures on one table (you can break this into two parts if the large-scale sculpture got very large) and gather students around for a reflection. Discussion questions could include:

- *What kinds of lines do you see?*
- *How did people change the paper?*
- *Did you have any surprises while you were working or now while you are looking?*
- *How was your experience working small-scale different than your experience working large-scale? Did you use your body differently? Which scale do you prefer?*
- *How is your experience of looking at a small-scale sculpture different than looking at a large-scale sculpture?*
- *Do any of these sculptures remind you of sculptures you saw during your museum visit? If so, how?*
- *How was your experience working on a group sculpture different from working on your individual sculpture? Did you get any new ideas from working with other people? Do you prefer to work individually or as part of a group?*

Suggestions for Further Investigation:

- Have students write about their sculptures. This could be as simple as coming up with a title for their work, or could consist of a longer written description, a how-to, or a personal narrative account.
- Lines and shapes are the building blocks of art. A discussion of line can just as easily be carried over to drawing, painting, printmaking and collage. Lines connect together to make shapes. You could talk about the shapes that were created in students' sculptures through inter-connecting lines. A discussion of lines and shapes can also be applied to learning handwriting skills (i.e. the alphabet is made up of simple lines and shapes).
- Notice the scale of things in your classroom. What is large-scale, what is small-scale and why? For instance, how are students' desks different than teachers' desks and why?

Artist work that can be used as a reference from this TRP are Bennett Battaile: *History* (p. 17), Edward Mayer: *Drawing In* (p. 24), and Hilal Sami Hilal: *Material Studies* (p. 23)

Activity 2: Deconstruct, Reconstruct: An Adventure in Lace and Knitting
Suggested Level: Grades 3-5
Time: One to two class periods

Objectives:

- To explore the possibilities of object making by dismantling and rebuilding to achieve or invent lace.
- To begin to identify with creative and expressive values of Lace and Knitting.
- To understand the value of working as a community.
- To apply the principles of repetition, pattern, and unity, in order to make reference to something else.

Materials:

- Small cardboard boxes
- Scissors
- Hole punches
- Balls of yarn

Vocabulary:

- Lace
- Knit
- Deconstruct
- Scale
- Reference
- Social
- Community
- Repetition
- Unity
- Sequence
- Collaboration

Part One:

Lace can be thought of as a fiber that allows light to pass through it. Considering this definition, just about anything could be transformed into a lace-like material. Knitting is accomplished by interlocking loops as members or parts.

- *What are some examples of lace you see in everyday life?*
- *What are some new possibilities of using lace?*
- *How can we combine the use of lace with the process of knitting?*
- *What are some possible results?*

Part Two:

Provide each student with a small cardboard box. Using scissors, and/or their hands, orchestrate a session where students are deconstructing the box by cutting and shredding. Students should wind up with several pieces of cardboard of various shapes and sizes. Instruct students to also use hole punches to pierce holes in each individual shape.

Part Three:

Divide students into small groups of three or four. Distribute a ball of yarn to each group. Instruct students to create a new structure out of the cardboard using only the yarn as a mending agent. Let the groups work out creative solutions. *Remember: Try not to interfere with suggestions of what they should make.*

Part Four:

Bring groups together to present their final objects. The results should very drastically.

- *What were some of the problems that occurred and how were they solved?*
- *How did the overall scale change?*
- *What type of object resulted from our collective "knitting" with the yarn?*
- *How would you display your new object?*
- *How does light affect your object?*
- *Did any accidents occur that changed the final outcome?*
- *What would you change about it?*

Suggests for Further Investigation:

Students could continue this project by assembling all of their individual group projects into one large-scale piece or the process of deconstruction and reconstruction could be repeated with each individual project. This would allow students to explore the infinite possibilities of this process.

Artist works that can be used as a reference from this TRP are Liz Collins: *Illuminated Veins* (p. 14), Althea Merback: *Ancient Greek Pullover* (p. 15), Bennett Battaile: *History* (p. 17), and Elena Herzog: *Untitled* (p. 21)

Activity 3: Re-inventing Shape with Knitting and Lace
Suggested Level: Grades 6-8
Time: One to Two class periods

Objectives:

- To create and apply a cross disciplinary method to art making by using contemporary lace and knitting works of art as inspiration.
- To explore various elements and principles of design through collage, paying attention to the qualities of knitting and lace work (open, flowing, translucent, pattern, etc.).
- To use unconventional methods such as tearing, ripping and scribbling to invent both 2- and 3-dimensional shapes.
- To follow directions for creating symmetrical geometric shapes.
- To understand and apply the use of organic and geometric shapes.
- To learn to improvise and use spontaneity while creating.

Materials:

- Collage materials such as magazines, wallpaper, fabric, etc.
- Cardboard
- Pencils
- Rulers
- Scissors
- Glue sticks
- Colored construction paper (include white)
- Markers of various colors and sizes

Vocabulary:

- Positive and negative space
- Composition
- Geometric shapes
- Organic shapes
- Pattern
- Symmetrical
- Asymmetrical
- Spontaneous
- Cross-disciplinary

Part One:

Have students use spontaneous actions to create a wide variety of shapes using paper. This can be accomplished by making random marks and lines on paper, tearing or cutting the paper along those marks, and piecing them back together. This results in varying areas of positive and negative space, which become highly inventive shapes and patterns that can be both organic and geometric.

Procedure:

- Distribute cardboard to students. See to it that each student has a 12” x 12” sheet of cardboard. Use a ruler and measure out the dimensions that can accomplish this. Use a pencil and a ruler to divide the square up into 12 1” squares. Once all the squares have been outlined, divide each square diagonally from the upper left corner to the lower right. Instruct students to set the cardboard aside.

- Students will use markers to create random lines on their white sheet of paper. Encourage them to fill the paper with lines by scribbling, and using the ruler. Including the white paper, students will begin by tearing construction paper into various shapes and sizes. They will then compose a collage on the cardboard square (be sure to use the unmarked side) using the torn shapes and the glue sticks.
- Once the collage is complete, have students cut along the lines drawn on the backside of their cardboard. The result should be 24 equilateral triangles. Collect all of the pieces from the students in one container.

Part Two:

Students will be given 24 randomly selected triangles from the source. They will then be asked to compose a new image within the guidelines of a 12" x 12" square.

Part Three:

Students should display their work as a group and discuss the different ideas behind the compositions.

- How many different types of shapes can you point out?
- Which shapes read positive and which negative?
- Which shapes are organic?
- Which shapes are geometric?
- Is there any indication of texture?
- How does your composition resemble lace?
- How did we use mathematics?
- Point out some areas where accidents or random acts created interesting compositions?

Suggestions for Further Investigation:

- Combine all of the individual projects to form one mural in the classroom (or public space in the school).
- Consider having the students glue their shapes down to an additional 12"x12" inch board and experiment with new geometric divisions by repeating the process. This will allow them to experiment not only with mathematics, but also the art of creative innovation.
- Have students work without a base—perhaps on the wall or floor--paying attention to negative and positive space again, but also shadows cast in the process and the space in which they work gets transformed.

Artist works that can be used as a reference from this TRP are Barbara Zucker: *Lillian's Face Flowing* (p. 13), Henk Wolvers: *Material Studies* (p. 18), Shane Waltener: *Auntie Peggy Has Departed* (p. 20), Elena Herzog: *Untitled* (p. 21), and Hilal Sami Hilal: *Material Studies* (p. 23)

Activity 4: Lace-Like Installations
Suggested Level: Grades 9-12
Time: 2-3 sessions

Objectives:

- Students will understand that sculptures can be created for a specific location.
- Students will understand that a familiar space can be transformed through installation art.
- Students will understand that lines can be organized in a pattern to create a lace-like structure.
- Students will be able to work together to create a site-specific lace-like installation.

Materials:

- Scissors
- Clear packing tape

A variety of materials which could include--

- String
- Ribbon
- Dental floss
- Strips of paper
- Strips of cardboard
- Rope
- Yarn
- Thread
- Wire
- Fishing line (monofilament)

Vocabulary:

- Sculpture
- Three-dimensional
- Large-scale
- Site-specific
- Installation
- Pattern
- Lace-like
- Delicate
- Industrial
- Weave
- Subversive
- Transform

Part One:

Review your visit to the Museum focusing on site-specific installations. Sometimes artists create site-specific installations. This is an art creation, often large-scale, that is made to transform a specific place, giving viewers a new experience of that space. Several installations in this exhibition were specifically created for spaces in the museum.

- *Have you ever transformed a space in your house? Maybe you used chairs, tables, blankets, etc. to create a fort?*
- *Did you notice any art creations in this exhibition that seemed to transform part of the museum? What were these installations made out of?*
- *This exhibition focuses on knitting (using a single fiber to create a structure) and lace (a structure, using fiber, which allows light to pass through). Did any of the installations transform your idea of what knitting or lace can be?*
- *Did any of the installations remind you of lace and why? Did any of the installations allow light to pass through and how? Did any of the installations contain patterns?*
- *Where else have you seen structures like these? In nature? In the city?*

Part Two:

a) As a class, discuss spaces in your classroom or school that could use a transformation. Maybe it is a space that goes unnoticed. Maybe it is a highly trafficked space. Maybe it is a corner, maybe it is underneath a table, maybe it is two spaces that could be connected together through art. Go visit these spaces, make sketches and measurements. Try to think about the function and/or history of the space or place you have chosen.

b) Now imagine how you could transform one of these spaces, specifically using lace-like patterns. What materials would you use? Would the material be delicate, or industrial? Would you use muted or vibrant colors? Would you let a lot of light pass through, or just a little? What kind of pattern would you create? Sketch some of your ideas.

c) Discuss sketches. Which idea is the most practical? Which idea is the most subversive? Which idea is the most lace-like? Which idea is the most transformative?

d) As a group, decide if you will work all together on one installation, or break into smaller groups to create several installations. Decide as a group what materials you would like to use and start to collect these materials.

Part Three:

With materials ready, imagine how you will connect your materials together.

- *Will you need to glue pieces together?*
- *How about weaving, draping, knotting?*
- *Will you need tape to connect pieces to the site?*
- *Are there any kinds of hooks or places at the site that you can connect to?*
- *Do you need any hardware to use as anchors (such as a chair or table)?*
- *To create your lace-like pattern, where do you need to start?*
- *Will there be different layers?*

Work as a group to create an action plan, and a role for each person (and this might include taking turns).

Create site-specific lace-like installations.

Part Four:

Visit each installation for a reflection. Discussion questions could include:

- *How does this installation transform the space? Describe what you see and what you are experiencing. How is it lace-like?*
- *Refer back to the drawings. Which one followed the original plan the closest? Which one changed the most from the original plan?*

- *Which installation is the most subversive? Which installation is the most lace-like? Which installation is the most transformative?*
- *Do any of the installations remind you of any of the installations you saw at the museum and why?*
- *What was your experience of planning, creating and viewing these installations?*

Suggestions for Further Investigation:

Conduct some peer research. Interview another class about their experiences with your installations.

- *Were they surprised?*
- *Did your installation change the way they noticed the space?*
- *Did it change the way they look at other spaces?*
- *Are they noticing what you want them to notice?*
- *Would you change anything based on their feedback?*

Create a display documenting your museum visit and the process your class went through to create each installation.

Artist works that can be used as a reference from this TRP are Shane Waltener: *Auntie Peggy Has Departed* (p. 20), Cal Lane: *Untitled* (p. 22), and Edward Mayer: *Drawing In* (p. 24).

Glossary

Asymmetry - when one side of a composition does not reflect the design of the other.

Bend – To force from a straight form into a curved or angular form or from a curved form into some different form.

Casting on – the beginning stage of knitting where the yarn is attached with a slip knot to one of the knitting needles.

Chiffon – a kind of soft gauzy material.

Collaborate – work with others on a joint project.

Collage – Collage is from the French meaning "paste up". The combination of pieces of cloth, magazines and other found objects to create artwork.

Community – group of people who interact and share certain things as a group.

Composition – the arrangement of lines, colors and form.

Cotton - a soft fiber that grows around the seeds of the cotton plant (Gossypium spp.), a shrub native to the tropical and subtropical regions of Africa and the Americas. The fiber is most often spun into thread and used to make a soft, breathable textile, which is the most widely used natural-fiber cloth in clothing today.

Crochet – needlework made by looping thread or yarn with a hooked needle.

Cross-Disciplinary - connecting skills and knowledge from multiple sources and experiences.

Crumple – to press or crush into irregular folds or into a compact mass.

Curl – to form into coils or ringlets, a spiral or curved shape.

Deconstruct – to take apart.

Delicate – fine in texture, quality, construction, etc.

Embroidery – is the art or handicraft of decorating fabric or other materials with designs stitched in strands of thread or yarn using a needle. (Embroidery can also be made using other materials such as metal strips, pearls, beads, quills, and sequins.)

Fiber - for this exhibition, fiber refers to a wide range of materials that can be manipulated to create knotted or linked structures.

Flameworked glass – gas torches are used to shape the glass.

Flameworking – a glass technique where thin rods of glass are heated with a small, concentrated flame to bend them and attached them to each other.

Fold – to bend over upon itself.

Form – an element of art, such as you would see in a sculpture that has three dimensions.
A shape; an arrangement of parts.

Fuse – to combine or blend by melting together.

Geometric – resembling or employing the simple rectilinear or curvilinear lines or figures used in geometry (circle, square, triangle etc.)

Glass - basic elements of sand, soda lime are combined with coloring agents, and melted together to produce the raw material.

Guerilla - method of combat by which small groups of combatants attempt to use mobile and surprise tactics (ambushes, raids, etc) to defeat a foe.

Hilbert space filling curve – a line that is continually doubled back on itself by bending it again and again until it fills up an entire space.

Industrial – of, pertaining to, of the nature of, or resulting from industry.

Installation – something that has been installed in a specific space.

Knit grafting - knitting multiple rows of narrow cords and, once every several rows, attaching a piece of non-knit fabric to the knitting structure so that they “fuse” together.

Knitting – a technique using a single element or yarn in which a loop is drawn through a previous loop at the edge of a fabric. For this exhibition, knitting is taking a single fiber and creating a structure from it.

Lace - patterned openwork fabric made by plaiting, knotting, looping, or twisting. The finest lace is made from linen thread. Handmade laces include needlepoint and bobbin lace, tatting, crochet work, and some fabrics made by netting and darning. For this exhibition the definition of lace is a structure made out of some sort of fiber that allows light to pass through it.

Lace-like – having the qualities of lace.

Large-scale – the proportion that is a representation of an object that is more than average size to the object itself.

Lead – a soft, heavy, toxic and malleable poor metal, lead is bluish white when freshly cut but tarnishes to dull gray when exposed to air.

Line - A line is an identifiable path of a point moving in space. It can vary in width, direction and length.

Linen - is a material made from the fibers of the flax plant.

Industrial Shelving – heavy duty shelving.

Miniature - a representation or image of something on a small or reduced scale.

Nålebinding – an ancient craft which involves creating fabric from thread by making multiple knots or loops.

Negative space – empty space in an artwork, a void.

Organic - shapes that are not regular or even, using a combination of edges that are curved or angular.

Pattern - the repetition of any thing -- shapes, lines, or colors -- also called a motif, in a design; as such it is one of the principles of design.

Polyester - usually, polyester refers to cloth woven from polyester fiber. Polyester clothing is generally considered to have a "less natural" feeling to it compared to natural fibers. Polyester fibers are often spun together with fibers of cotton, producing a cloth with some of the better properties of each.

Porcelain – a hardy clay body which is glasseous white and sometimes translucent.

Positive space – space in an artwork that is positive — filled with something, such as lines, designs, color, or shapes

Purl stitch – is a basic knitting stitch. It is a knit stitch done backwards.

Radical – extreme as regards change from accepted or traditional forms.

Reference – something that refers to or designates something else, or acts as a connection or a link between two things.

Repetition – to do the same thing over and over.

Ribbon - a woven strip or band of material, varying in width and finished off at the edges, used for ornament, tying, etc.

Rubber – A yellowish, amorphous, elastic material obtained from the milky sap or latex of various tropical plants, especially the rubber tree that is modified and finished to make products such as electric insulation, elastic bands and belts, tires, and containers. Or, any of numerous synthetic elastic materials of varying chemical composition with properties similar to those of natural rubber.

Scale –a proportion used in determining the dimensional relationship of a representation to that which it represents; the ratio between the size of something and a representation of it.

Sculpture – the art of carving, modeling, welding, or otherwise producing figurative or abstract works of art in three dimensions, as in relief, intaglio, or in the round.

Sequence – the following of one thing after another.

Shape – shapes can be in the form of squares, circles, triangles, rectangles, and ovals.

Silk – filaments secreted by caterpillars and spiders. While the silk of most caterpillars and spiders is not practical for textiles, there are a few species of moths whose cocoons yield usable fiber.

Site-specific – created, designed, or selected for a specific site.

Skein - a small, coiled bundle of yarn or thread.

Small-scale – the proportion that is a representation of an object that is less than average size to the object itself.

Social – seeking or enjoying the companionship of others.

Spontaneous – coming or resulting from a natural impulse or tendency; unplanned.

Stitch – (a) A single loop of yarn around an implement such as a knitting needle. (b) The link, loop, or knot made in this way. A mode of arranging the threads in sewing, knitting, or crocheting: *a purl stitch.*

Subversive – likely to destroy or overthrow.

Symmetry - when one side of something balances out the other side.

Synthetic - made in a laboratory.

Textile – anything made by people from fibrous materials.

Three-dimensional – having, or seeming to have, the dimension of depth as well as width and height.

Transform – to change in form, appearance, or structure.

Twist – to combine, as two or more strands or threads, by winding together.

Unity – a whole or totality as combining all its parts into one; oneness.

Weave – to form by interlacing threads, yarns, strands, or strips of some material.

Wire - a single, usually cylindrical, elongated strand of drawn metal.

Wool - the fiber from the outer coat of primarily sheep and goat.

Yarn – the general term for any assemblage of fibers that has been put together in a continuous strand suitable for weaving, knitting and other textile techniques.

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Yoshiki Hishinuma	www.yoshikihishinuma.co.jp
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www.laceguild.demon.co.uk	English Lace Guild
www.kantcentrum.com	Lace Center in Bruges, Belgium
www.lace.lacefairy.com/LaceBookList	For a more in-depth lace bibliography
www.learntoknit.com	Basic instructions to learn to knit and crochet

CRAFTY GEOMETRY

Mathematicians are knitting and crocheting to visualize complex surfaces

BY ERICA KLARREICH

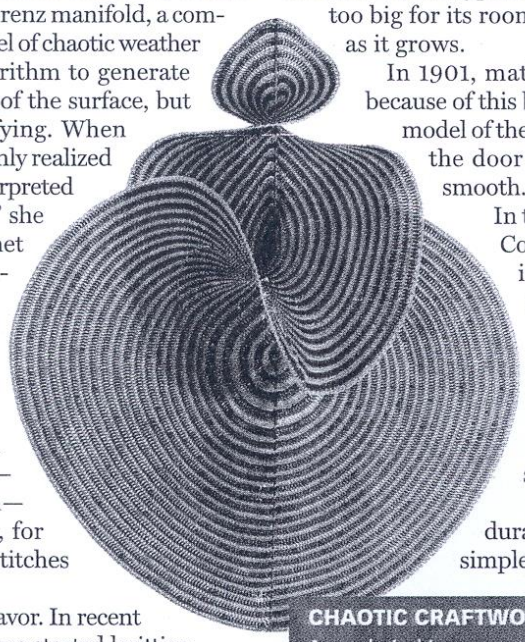
During the 2002 winter holidays, mathematician Hinke Osinga was relaxing with some lace crochet work when her partner and mathematical collaborator Bernd Krauskopf asked, "Why don't you crochet something useful?" Some crocheters might bridle at the suggestion that lace is useless, but for Osinga, Krauskopf's question sparked an exciting idea. "I looked at him, and we thought the same thing at the same moment," Osinga recalls. "We realized that you could crochet the Lorenz manifold."

For years, Osinga and Krauskopf, both of the University of Bristol in England, had been studying the Lorenz manifold, a complicated surface that emerges from a model of chaotic weather systems. The pair had created an algorithm to generate 2-dimensional computer visualizations of the surface, but Osinga found the flat images unsatisfying. When Krauskopf asked his question, she suddenly realized that the computer algorithm could be interpreted as crochet instructions. "I had to try it," she says. Eighty-five hours and 25,511 crochet stitches later, Osinga had a Lorenz manifold almost a meter tall and about 25 centimeters in diameter, which now hangs in the pair's house as a decoration.

Mathematics has long been an essential tool for the fiber arts. Knitters and crocheters use mathematical principles—often without recognizing them as such—to map the pattern of a cable sweater, for instance, or figure out how to space the stitches when adding a sleeve onto a jacket.

Now, the two crafts are returning the favor. In recent years, mathematicians such as Osinga have started knitting and crocheting concrete physical models of hard-to-visualize mathematical objects. One mathematician's crocheted models of a counterintuitive shape called a hyperbolic plane are enabling her students and fellow mathematicians to gain new insight into startling properties. Other mathematicians have knitted or crocheted fractal objects, surfaces that have no inside or outside, and shapes whose patterns display mathematical theorems.

"Knitting and crocheting are helping us think about math we already know in a different light," says Carolyn Yackel, a mathematician at Mercer University in Macon, Ga.



UNIV. BRISTOL

CHAOTIC CRAFTWORK — A crocheted Lorenz manifold brings the shape's swirls into sharp relief.

A HYPERBOLIC YARN In 1997, as Daina Taimina geared up to teach an undergraduate-geometry class, she faced a challenge. As a visiting mathematician at Cornell University, she planned to cover the basic geometries of three types of surfaces: planar, or Euclidean; spherical; and hyperbolic. She knew that everyone can use intuition to conceive of the first two geometries, which are the realms of, say, sheets of paper and basketballs. The hyperbolic plane, however, lies outside of daily experience of the physical world.

Geometry teachers usually try to explain the hyperbolic plane via flat models that wildly distort its geometry—making lines look like semicircles, for instance. How, Taimina wondered, could she give her students a feel for hyperbolic geometry's counterintuitive properties? While attending a workshop, the answer came to her: Crochet a piece of hyperbolic fabric.

In a flat plane or a sphere, the circumference of a circle grows at most linearly as the radius increases. By contrast, in the hyperbolic plane, the circumference of a circle grows exponentially. As a result, the hyperbolic plane is somewhat like a carpet that, too big for its room, buckles and flares out more and more as it grows.

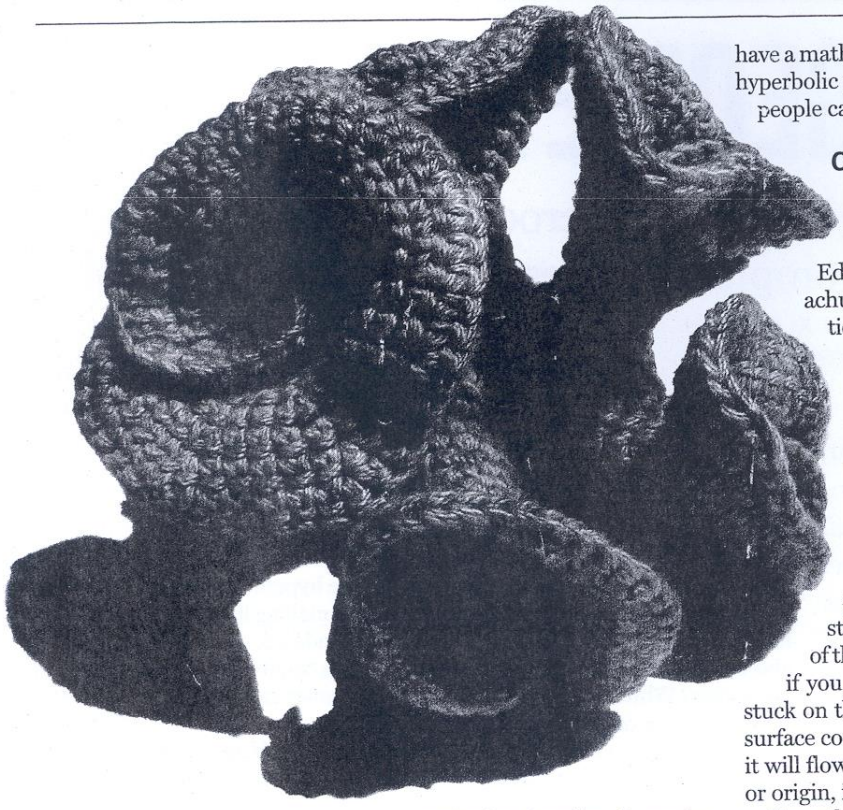
In 1901, mathematician David Hilbert proved that because of this buckling, it's impossible to build a smooth model of the hyperbolic plane. His result, however, left the door open for models that are not perfectly smooth.

In the 1970s, William Thurston, now also at Cornell, described a way to build an approximate physical model of the hyperbolic plane by taping together paper arcs into rings whose circumferences grow exponentially. However, these models take many hours to build and are so fragile that they generally need to be protected from much rough-and-tumble hands-on study.

Taimina realized that she could crochet a durable model of the hyperbolic plane using a simple rule: Increase the number of stitches in each row by a fixed factor, by adding a new stitch after, for instance, every two (or three or four or n) stitches. In 2001, Taimina and her Cornell colleague David Henderson proved that the crocheted objects indeed capture the geometry of the hyperbolic plane. Over the past decade, Taimina has crocheted dozens of these models.

Taimina's models have made it easy to study hyperbolic lines—the shortest paths between two points on the hyperbolic plane. Given two points, all that's necessary is to grab each point and gently pull tight the fabric between them. The line can then be marked, for future reference, by sewing yarn along it.

Taimina has used these sewn lines in the classroom to illustrate the hyperbolic plane's most famous property. The plane violates Euclid's parallel postulate, which states that given a line and a point off the line, there is just one line through the point that never



HYPERBOLIC FABRIC — Many of the lines that could be inscribed on this crocheted hyperbolic plane curve away from each other, defying Euclid's parallel postulate.

meets the given line. By sewing lines with yarn, Taimina's students have observed that in the hyperbolic plane there are, in fact, infinitely many lines through a given point that never meet a given line. Loosely speaking, this happens because the hyperbolic plane's extreme flaring makes certain lines veer away from each other instead of intersecting as they would in a flat plane.

Because the hyperbolic plane is so hard to visualize, Taimina's crocheted models are helping even seasoned mathematicians develop a better intuition for its properties. Taimina recalls that one mathematician, upon examining one of her hyperbolic planes, exclaimed, "So that's what they look like!"

Taimina has crocheted models for many mathematics departments and for the Smithsonian Institution as examples of math teaching tools, but she now thinks twice before agreeing to make someone a model. Because of the exponential growth, crocheting a hyperbolic plane takes a long time. For instance, one of Taimina's models started with a 1.5-inch row, but the 20th row was already more than 30 feet long. What's more, the crochet work is hard on the hands, Taimina says, since the stitches must be tight to prevent the fabric from stretching out of its characteristic hyperbolic shape. Luckily for Taimina, many mathematicians "are now enthusiastically making their own models," she says.

Taimina's hyperbolic planes have also attracted interest from art lovers. Her models have appeared in art shows all over the United States, and some are currently on display in Latvia and Italy.

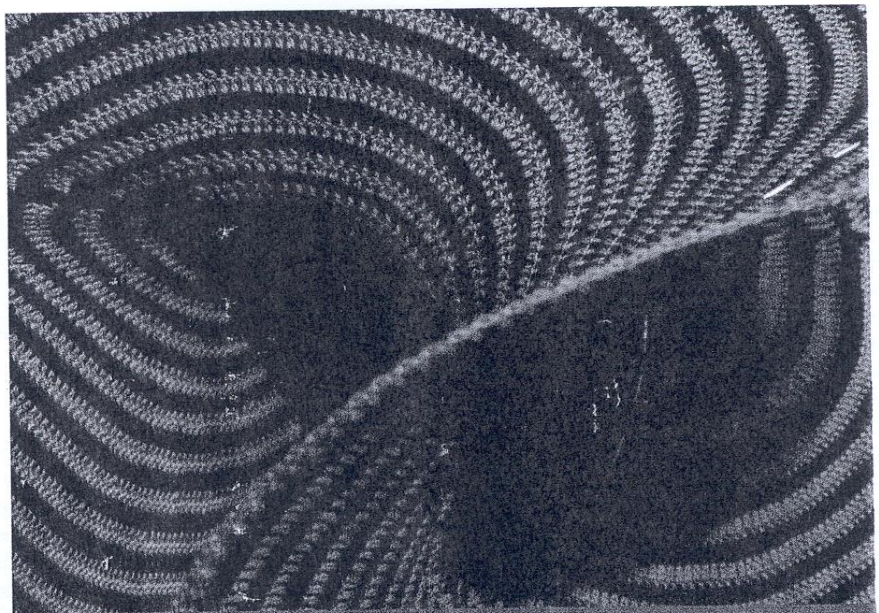
"I have met so many people now who don't have a math background, but who want to understand what these hyperbolic planes mean," Taimina says. "It makes me happy that people can learn beautiful geometry and not be intimidated."

CROCHETED CHAOS Osinga launched her crochet project in the hopes of finally getting her hands on a Lorenz manifold, a mathematical object that she had been studying theoretically for years. Meteorologist Edward Lorenz, now an emeritus professor at the Massachusetts Institute of Technology, had set down three equations in 1963 as a highly simplified description of weather dynamics. These Lorenz equations have tremendous mathematical and historical significance. While simulating the equations' dynamics on a computer, Lorenz found that tiny round-off errors result in hugely different outcomes, a discovery that launched the field of chaos theory.

Osinga explains that Lorenz' equations describe a flow in three-dimensional space, and the Lorenz manifold corresponds to a certain specific part of a river. "If you throw a leaf in the water and watch it flow downstream toward a rock, the leaf might go to the right or left of the rock," she says. "But there are particular points where, if you drop the leaf exactly there, it will flow down and get stuck on the rock." The Lorenz manifold is the two-dimensional surface consisting of all the points where you can drop a leaf and it will flow to the rock, which is represented by the central point, or origin, in a three-dimensional coordinate space.

Since the system is chaotic, the Lorenz manifold twists around with many changes in curvature. To build a computer image of the surface, Osinga and Krauskopf devised an algorithm that starts at the origin and works its way outward in concentric rings. For each ring, the algorithm looks for points from which an object would flow to the origin. The algorithm can't find all such points, since there are infinitely many, so instead it identifies a collection of prototypical points that are about evenly spaced along the surface and then connects neighboring points by links so that the resulting mesh will resemble the Lorenz surface. In areas where the surface has floppy, hyperbolic geometry, the algorithm will identify many mesh points; where the surface has more tightly curved geometry, the algorithm will identify fewer points.

Osinga realized that the mesh instructions could be read as a cro-



OFF THE HOOK — Line-by-line crocheting instructions that tell where to increase or decrease numbers of stitches create the global shape of the Lorenz manifold.

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chet pattern: Crochet outward in rings and simply add or remove stitches to suit the mesh pattern. As the fabric grew under her nimble fingers—Osinga has been crocheting since age 7—it automatically took on the curvature of the Lorenz manifold.

"Just local information about where to increase stitches created the entire global shape," Osinga says. When Osinga had finished crocheting, she and Krauskopf mounted the fabric on garden wire, and it indeed took the shape of the Lorenz manifold, Osinga says.

Unlike Taimina's hyperbolic planes, whose crochet instructions can be summed up in a single sentence, the instructions for the Lorenz surface fill two pages of a paper that Osinga and Krauskopf published in 2004. "An expert needleworker will be able to [crochet a hyperbolic plane] while having a nice conversation or watching TV," the pair say in the paper. "Crocheting the Lorenz manifold, on the other hand, requires continuous attention to the instructions in order not to miss when to add or indeed remove an extra crochet stitch."

Despite the difficulty of making a Lorenz manifold, Osinga hears regularly from crocheters trying to follow her pattern, which is available at a link from her Web site. "I get emails from crafters who are not at all scientifically inclined but want to understand what they are making," she says. "They ask very intelligent math questions."

Like Taimina's hyperbolic planes, Osinga's Lorenz manifold has taken to the road frequently since its construction, making appearances at mathematical conferences, at art shows, and even on television news. "In my teaching, the students take me way more seriously now," she says. "This complicated math I do, which seems so useless, gets you on TV."

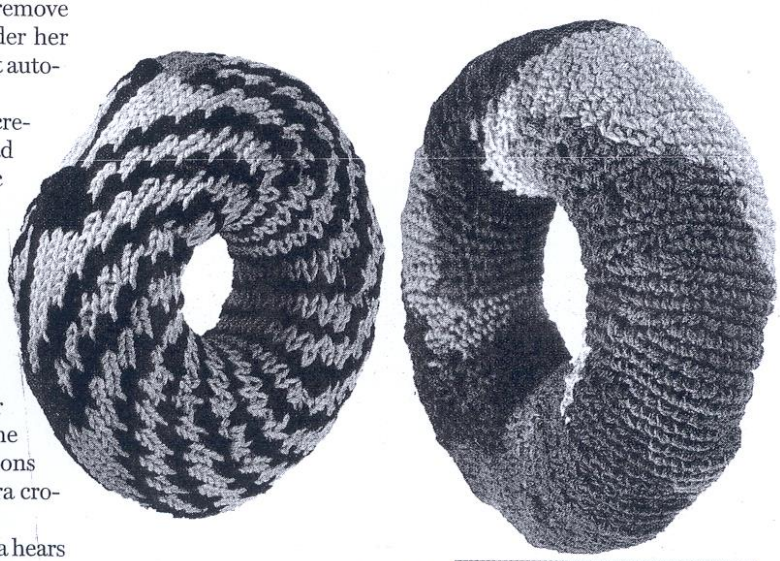
A MENAGERIE OF MODELS

While Taimina's and Osinga's models have achieved the most fame, a host of other mathematicians in recent years has started crocheting and knitting mathematical shapes. An exhibit of mathematically inspired fiber arts at the 2005 annual Joint Mathematics Meeting in Atlanta boasted an impressive array of such models. In addition to Taimina's hyperbolic planes and a Lorenz surface crocheted by Yackel, the exhibit featured Möbius strips, which are twisted rings that have only one side, and Klein bottles, which are closed surfaces that have no inside. There were also crocheted versions of the five Platonic solids—the cube, the tetrahedron, the octahedron, the dodecahedron, and the icosahedron—as well as a bricklike fractal object called Menger's sponge.

It's not clear just why mathematical craftwork has suddenly taken off, says sarah-marie belcastro, a mathematician at Smith College in Northampton (Mass.), who organized the exhibit with Yackel. "Part of me says it's because there are so many more women in math now," she says. "But every time we give talks, there are men in the audience who say they knit or crochet."

For a gathering last March in Atlanta to honor mathematics writer Martin Gardner, belcastro and Yackel created doughnut-shaped surfaces, called tori. The patterns on their tori illustrate two well-known mathematical ideas about maps and networks on a torus.

Given a map showing several countries, consider the ways to color each country so that no neighboring countries have the same color. In 1976, mathematicians famously proved that in the flat plane, no such map would require more than four colors. On a torus, however, where there are more ways for a country to wrap around and touch another country, mathematicians showed as long ago as 1890 that as many as seven colors can be required. Yackel's crocheted torus displays one seven-color map that, remarkably, has only seven countries on it—every country touches every other.

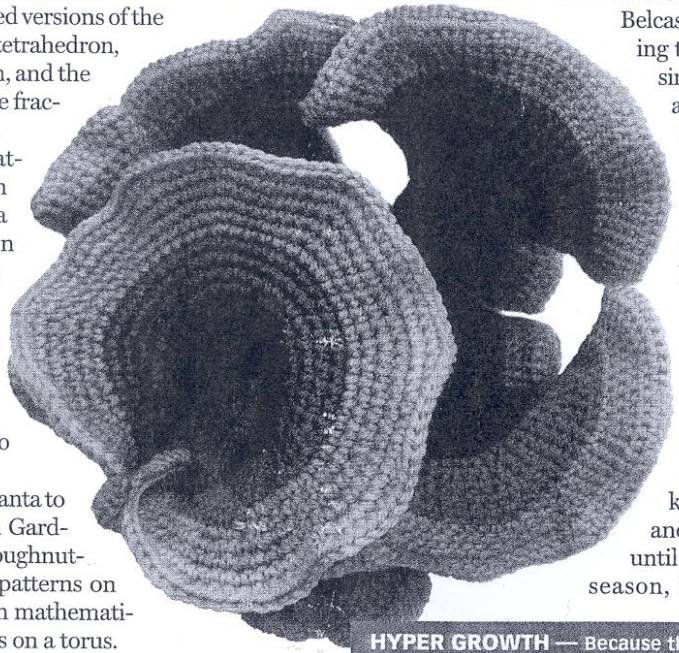


DOUGHNUT MATH — The two tori at top display a network (left) and a colored map of countries (right) that can't be depicted on a flat sheet of paper without crossings and overlaps.

Belcastro's knitted torus, which can be seen as a companion piece to Yackel's, displays an intriguing fact about networks on the torus. The torus depicts a collection of points connected by paths. This network is derived from the map on Yackel's torus by marking one point inside each country and then connecting each pair of points by a path, like a railroad line, that crosses the boundary between their respective countries. Such a network of seven points, each connected to every other by a path, can't be drawn in the flat plane without some paths crossing. On the torus, however, as belcastro's knitting demonstrates, the paths can snake around the hole and avoid each other.

Belcastro and Yackel thought that making the tori would be a simple matter since pictures of the seven-color map and the corresponding network on the torus are readily available. However, it turned out to be "a nightmare," belcastro says. The challenge was figuring out how to make lines and boundaries look smooth despite the discrete nature of the stitching.

Yackel and belcastro are now editing a book to be called *Making Mathematics with Needlework*. It will feature patterns and mathematical discussions of 10 craft projects, including knitting, crocheting, embroidery, and quilting. The book isn't due out until spring. Nevertheless, this holiday season, instead of the ubiquitous gift sweater, you might want to consider knitting a Möbius scarf or a Klein bottle hat, or crocheting some hyperbolic Christmas tree ornaments. ■



HYPER GROWTH — Because the hyperbolic plane grows exponentially, the violet outer boundary consumes as much yarn as the deep-purple center section does.