Visual Syntax and Intelligence

a study in designing for multiple perspectives

Thesis Approval sheet

05/18/01

Professor R. Roger Remington DATE

Chief Advisor

5/18/01

Professor Bill Finewood DATE

Committee Member

5/18/01

Professor Steve Loar DATE

Committee Member

5/22/01

Nancy Ciolek DATE

Chairperson

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5/23/01

Tanya J. Harding DATE

Designer

Visual Syntax and Intelligence
a study in designing for multiple perspectives

by Tanya J. Harding

Submitted to the Graduate Graphic Design Program,
School of Design, College of Imaging Arts and Sciences,
in partial fulfillment of the requirements for the
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Thesis Advisor

Professor R. Roger Remington
Thesis Advisor
Design History Professor
Graduate Graphic Design Professor
College of Imaging Arts and Sciences
Graphic Design Department

Committee Members

Professor Bill Finewood
Illustration Professor
College of Imaging Arts and Sciences
Illustration Department

Professor Steve Loar
Foundations Professor
College of Imaging Arts and Sciences
Foundation Department

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Everyone who fed me coffee
Everyone who fed me

Table of Contents

Man is the total sum of his experience. His scale and focus change continuously as he studies, grows and develops. Therefore, in designing, we must realize that steadily changing conditions confront us, to which we can only adjust ourselves by: constantly developing better and more precise ways of expressing ideas; investigating anew with each new assignment the entire range of approaches; understanding the mechanics of vision. The designer stands between these concepts, at the center, because of his unique role as communicator, link, interpreter and inspirer. Thus he creates.

Will Burtin, excerpt from "Integration; the New Discipline in Design" Graphis No 27, 1949

Situation and Problem Analysis

This thesis project is concerned with the role that graphic designers have in making learning materials more effective. It is focused on the need for instructional materials to reflect current advances in cognitive psychology and our society's definition of intelligence.

Most instructional materials today are outdated and ineffective. Some reasons are political, others are socio-economic, and some fall within the scope of the designed environment. Learning materials, especially textbooks, designed before the 1980's have been designed without standards, and at a time when intelligence was seen as a narrow list of abilities.

History of the problem

In 1904, the minister of education in Paris, France commissioned the French psychologist Alfred Binet to create a method to determine "at risk" students. Binet's work resulted in Intelligence Quotient tests. They became widespread in the United States, hand in hand with the notion that intelligence could be measured as an Intelligence Quotient (IQ). Consequently, intelligence was accepted as being a single capacity that drives only logical and mathematical thought.

Today, we have become enslaved by this definition. We rely on outdated materials and methods of teaching and assessment. We allow this view of intelligence to affect the classroom environment, curriculum and the methods of teaching.

As of the late 1980's, great debates on education have called for reform. In fact, psychologist Howard Gardner refutes the outdated definition and reminds us of Alfred Binet's own comments on the previously mentioned intelligence tests;

Howard Gardner presented his Multiple Intelligence theory in the book ***Frames of Mind***, published in 1983 by Basic Books.

> "The scale, properly speaking, does not permit the measure of the intelligence, because intellectual qualities are not superposable, and therefore cannot be measured as linear surfaces are measured."

Howard Gardner proposes the theory that there are multiple intelligences. He suggests a broader scope of human potential in his Multiple Intelligence Theory. According to Gardner, all individuals possess eight intelligences. These, in various combinations, allow people to use different skills to solve the same problem. Unlike other intelligence theories that differentiate personality types or learning environments, MI theory explains the processes that the mind uses to understand information in the world around it.

As communicators, graphic designers have the same concerns. This has great impact on our understanding of how people learn and therefore, on how we should design instructional materials.

To date, educators have taken the brunt of responsibility for reforming educational programs. **This thesis project proposes that graphic designers have a responsibility and have a role in creating more effective learning materials, therefore aiding in the reform.** (See Appendix A for full thesis Proposal)

Thesis design application

This thesis project is a study of the graphic designer's role in creating more effective learning material, and will result in a printed design application that will exist as a model for future instructional materials. It will incorporate current knowledge of educational psychology and be based on Howard Gardner's Multiple Intelligence Theory. The resulting model is an example demonstrating one way to broaden the scope of instructional materials, allowing children to grasp information using many combinations of skills.

The resulting precedents are resources that validate the need for reform in instructional design, experiment with graphic design, and show the success of MI theory application.

Projects applying Multiple Intelligence Theory

Project Zero
Harvard University
Graduate School of Education
124 Mount Auburn Street
Cambridge, Massachusetts 02138
http://www.pz.harvard.edu

The first stage of this project relied heavily on collecting the documented successes of MI theory and its application. The researchers at Project Zero have a long history of being at the forefront of school reform. Even though graphic design is not addressed specifically, the success or failure of the thesis design application relies on their success.

Project Zero was created in 1967 by the philosopher Nelson Goodman. David Perkins and Howard Gardner became the co-directors of Project Zero in 1972. At first it was founded to study and improve education in the arts. Over the years, however, Project Zero has continued to expand its scope. Now they apply experimental educational theories to individuals, whole classrooms, schools, and other educational and cultural organizations as well. The programs they offer promote the application of Howard Gardner's Multiple Intelligence Theory and have successfully given support to other programs that hope to do the same. The following are only three of the forty or more programs that Project Zero has been involved with successfully.

Multiple Intelligences Schools
Project Managers: Mara Krechevsky and Mindy Kornhaber
1992

This project was a research study examining the many ways Multiple Intelligences theory has been applied in schools, as well as the types of impact it has made. Researchers conducted phone interviews with principals from eleven schools that have devised their own programs based on MI theory, and conducted site visits at nine of these schools. The initial findings suggest that MI helps schools in several ways. It offers a vocabulary for teachers to use in discussing children's strengths and in developing curricula; it validates the practices of teachers whose work is already synchronous with MI theory; it promotes or justifies education in diverse art forms; and it encourages teachers to work in teams, complementing their own strengths with those of their colleagues. It also encourages schools to devise rich educational experiences for children from diverse backgrounds.

Project Spectrum
Principle Investigators: Howard Gardner and David Henry Feldman
1984 to 1988
Based on the theory that every child exhibits a distinctive mixture and spectrum of abilities (intelligences), this project offered an alternative approach to assessment and curriculum development during preschool and early primary years. Some of the methods explored were: assessment through student portfolios, teaching methods that incorporate hands-on learning and innovative cooperative learning methods.

ATLAS Communities; Communities for Authentic Teaching, Learning, and Assessment for all Students
1992
This project begins to answer the question, how would you design a school so that the curriculum is organized around essential questions? It was dedicated to revising curriculum standards for "break-the-mold schools" for the 21st century, and included Multiple Intelligence theory to define its goals.

New models proposed for designing

Developing Textbooks That Teach; A Problem solving Model of Textbook Design
By John Wakefield
TAA National Convention 1997
Professor of Educational Psychology
University of Alabama

There exists no formal and specific study of textbook, or instructional design. The design is left to the devices of the author. John Wakefield, an educational psychologist at the University of Northern Alabama, presented a paper on textbook design at the Text and Academic Authors National Convention (Appendix B). He suggests that an entirely separate field in instructional design should be created, emphasizing that this is a crucial problem graphic designers should respond to. He describes the current state of learning materials as being an "ill-structured problem".

Experimental designs for learning materials

The Pantheon Story of Mathematics for Young People
Witten by James T. Rogers
Designed by Will Burtin (1908-1972)
1966 Pantheon Books
Archives and Special Collections
Rochester Institute of Technology

Will Burtin, a significant information designer, published a children's math book with writer, James T. Rogers. It begins with a quote by Morris Kline, Professor of Mathematics, New York University, "However much inspiring teachers may seek to enliven calculation, it is on the whole rather dry."

His work on this math book proves that mathematics can become more stimulating with the correct treatment. Color and language coding systems were used to create a more memorable learning experience. It was designed very cleverly to be a mixture of storybook and reference book simultaneously. Will Burtin's ability to describe complex concepts in a simple way is a strong demonstration of the power graphic design has on making difficult information stimulating and easily digested. When designing pages of a US Army Air Forces training manual he states,

> *" Each aerial gunner had to learn his gun's mechanism inside out in the shortest possible time. Consequently the message had to be direct and swiftly to the point. A movie was considered for the purpose but tests proved that movies had poor memory value in terms of detail, even in repeated showings. Therefore a loose leaf manual was chosen, retaining as much as possible of cinematic techniques....photographs were silhouetted so as to bring out detail and interpose no square half-tone blocks in the visual stream. Titles were pulled out of the text blocks, set bold to facilitate an easy visual grasp of the subject, but set no larger than the body type to avoid disrupting in the sequence of operations..."*
>
> *Will Burtin, excerpt from "Interrelations"*
> *Graphis No 22, pp108-122*

"Design is intrinsically human. It is a plan and a process."[10] Research is a crucial step in creating meaningful design solutions. This project benefited from thorough research in several different areas. The subjects included were: cognitive psychology, graphic design for children, Multiple Intelligence Theory, instructional design, color theory, the "constructivist classroom", alternative teaching methods and more. As a whole the information gathered, from resource people, books and other sources, became the basis for the decisions in the thesis design application. The following is a summary of the research conducted.

INTERVIEWS

If "the best ideas in design reside in the areas between the disciplines," opening discourse about Multiple Intelligence Theory and its application to designed material is a crucial step in designing. The following are descriptions of the discussions held.

Carla Katz
Learning Assistance Services
Learning Development Center
Rochester Institute of Technology
September 26, 2000
1:15 *p.m.*

Carla Katz provided valuable validation at the beginning of the project. Later she provided possible channels to follow while deciding on design approaches. She suggested contacting resource people in the psychology department and some of her colleagues, such as Jane Munt, who is a reading specialist at the center, Karen Quin, who specializes in teaching math through right brained techniques, Belinda Brice, who also works in the learning development center and Deborah Sunbeck, who has spoken publicly about the positive consequences of incorporating Multiple Intelligence Theory.

This information helped to narrow the scope of the project by, providing the entire range of variables that could affect the project and, specifically, the thesis design application. In so doing, specific boundaries were established. The thesis design application will not deal with designing for learning disabilities, such as dyslexia for example. Also, since the content of learning materials is specific to the age, defining the user is crucial. **Carla Katz was influential in deciding that the project's hypothesis**

would best be proven by providing a model for an audience of third and fourth graders. At this age, children have a wide vocabulary and are adept at following directions.

Belinda Brice
Learning Development Center
Rochester Institute of Technology
October 3, 2000
2:15 p.m.
Belinda Brice is a Study Skills Instructor, who teaches classes in Learning Styles and works with students in the Alternative Learning Department. She suggested looking into the biological characteristics of learning, and subjects such as visual therapy. This led to an interview with Eriko Myahara.

Eriko Myahara
Department of Psychology
Rochester Institute of Technology
October 6, 2000
2:15 p.m.
Eriko Mayahara teaches the course "Visual Perception". She was contacted in an attempt to find specific answers to how people learn from visual information. Of all the interviews, this was one of the least successful. Attempting to describe this design project became very difficult. She was unsure of the tasks that a designer has. From a friendly exchange across disciplines, this interview transformed into a discussion on the definition of design, the importance of researching across disciplines and the value of looking at all possibilities prior to landing on one path or one single solution to a problem.

Barbara Billingsley
Librarian, Manager
Rundell Library Children's Center
December 1, 2000
9:30 am
Barbara Billingsley was a truly pleasant addition to the project, and had an astounding amount of knowledge on the field of children's books, from educational to entertaining. One suggestion laid the foundation for the project. There are many different *kinds* of learning materials. What exactly was the designer defining as learning material? **Learning materials were broken down into two categories, exploratory and curriculum based.** The characteristics, pro's and con's were compared and discussed with her aid.

Curriculum Based learning materials - Textbooks, dittos and which workbooks whose content is based on the required curriculum, and concentrate on teaching the information that is required by it.

Exploratory learning materials - Experimental books, videos, interactive software, and other media whose content is a mixture of lessons that teach one subject or theme. Most learning kits are sold commercially, or are available in libraries.

Learning by Numbers Kit

Learning kits include a variety of materials. Their production is state funded.

Kathy Maslanka
Teacher, St. Pius Elementary School
Rochester, New York
January 30, 2001
9:30 am
Kathy Maslanka, a third grade teacher at St. Pius elementary school, allowed an interview to be conducted in her classroom. Insights were gained into the future user of the Design Application. The child's environment was surveyed and the working methods of the educator could be understood.

She validated Multiple Intelligence theory and mentioned that St. Pius is one of the elementary schools chosen to incorporate alternative teaching and assessment methods, such a Rubric system of grading and student portfolios.

If educators want to incorporate Multiple Intelligence teaching methods, and rubrics assessment methods or student portfolios, they must gather the materials themselves. This, as Kathy mentioned, can become tiresome and time consuming. Instructional materials that are designed to incorporate diverse teaching methods are greatly needed. Teachers want to teach, not gather materials for the next day's plan. She was very enthusiastic about a kit that contained many activities for different intelligences.

The activities that are most successful with her students are ones with the most variety. This would include group work, individual work, indoor and outdoor activities, etc. Many textbooks, especially in the higher grades, make learning a chore, she mentions. Mrs. Maslanka tends to keep a collection of story books and other exploratory materials in the classroom. She allows the children to get up and look through them for a change of pace, and even allows them to take them home at times. In her classroom are some three dimensional blocks and other "toys" to use. It is the ideal environment for learning material based on Multiple Intelligence theory, and with educators such as Kathy, they would be used to their fullest capacity to the benefit of everyone involved.

Curriculum based versus exploratory material

(See Appendix F for New York State Curriculum)
Curriculum based learning materials have been proven to contain formats that encourage final / indisputable answers, time limits, quantitative scores, individual learning, and comparisons between children and are limited to marking on paper. Considering that most curricula are still catching up to modern methods of teaching, it is unthinkable to rely solely on these materials. A new approach to their design will alleviate the negative consequences that result.

Students who have been sheltered from alternative learning materials generally do not interact with other students, feel unnecessary competition with other students and cannot understand the quantitative results of their assessment. One of the most harmful deprivations is the fact that most students do not receive an opportunity to revise, edit, or rethink their answers. Students learn to know the answer to a question for a certain amount of time and later release it from memory.

Exploratory learning materials can range from collected materials that a class can use as examples during lessons to learning kits that are provided by such publishers as Scholastic Publishers. They have been proven to aid in academic achievement (See Appendix G).

These materials engage the child in a continual process of self reflection, meditated learning and revision. The emphasis is on process, as much as it is on product. Many include higher order thinking skills, which as John Wakefield mentioned in his lecture, should be one of the highest priorities when designing learning texts. "Text materials that teach today need to facilitate higher–order thinking to be congruent with contemporary educational goals." Learning materials should allow the student to synthesize information, draw connections and evaluate as well as memorize and understand directions from reading.

Designing learning kits

(See Appendix H)

According to Dunn and Dunn, instructional packages are designed to facilitate academic achievement. One reason is that many senses and processes can be used to learn. For example, a design that includes instructional tapes can apply clear directions, music and storytelling techniques to learning. Most kits are designed to focus on one theme or subject, for example, Egyptian history. They can be designed to include building materials that stimulate Bodily Kinesthetic intelligence, games to stimulate Interpersonal intelligence and books to stimulate Linguistic intelligence in one kit. Dunn and Dunn state that they can also be easily designed to make the learning process individualized or group oriented.

The previously mentioned authors suggest the following steps to designing more effective learning material in their book, *Teaching Students Through their Individual Learning Styles: A Practical Approach*. Even though geared toward educators, the following seven steps to building kits can be useful to graphic designers approaching this problem.

Step 1

Identify the topic. For example, you may want your students to understand concepts or acquire skills related to parts of speech, a specific country, pollution, writing business letters, or solving problems.

Step 2

List the things you want the student to learn about the topic.

Step 3

If you plan to tape record simple learning objectives for your students, use such words as explain, describe, list and identify. For example, if you were constructing a package on nouns, the taped objective might be: "By the time you finish this package, you will be able to explain what a noun is and to recognize one in a sentence."

Step 4

Pretend you are teaching your class the most important aspects of the selected topic. Write out exactly what you would say to them.

Step 5

Develop visual, tactual, and kinesthetic activities that emphasize these aspects in different ways. Write the directions for each of the activities as they will be taped, or written in the directions.

Step 6

Make up a short test that will reveal whether the student has learned the skills and concepts after using the package. This may be recorded as well as written.

Step 7

Use colorful cardboard box with a design that reveals the topic and contents. Cover the entire box, including the typewritten topic and contents, with clear laminate them to ensure longevity.

Defining Multiple Intelligences

Howard Gardner provides a way of tracking a range of human abilities by grouping them into eight well defined intelligences; Linguistic, Logical mathematical, Spatial, Bodily kinesthetic, Musical, Interpersonal, Intrapersonal and Naturalistic. They work in unison and in a variety of interesting ways. None exists by itself, and each always interacts with the others. **For graphic designers, they provide eight different ways that information can be understood, and therefore eight different ways information could be presented to people. This becomes a key element in finding solutions to the design problem.**

Linguistic intelligence includes the ability to control the syntax, phonology, meaning, syntax and semantics of words and language. Graphic Designers apply and exploit this intelligence in others when incorporating language systems into designs.

Logical mathematical intelligence is used when dealing with numbers. Most classrooms rely on materials and tests that measure this intelligence but ignores the others. It is characterized by sensitivity to numbers and such processes as categorization, calculation, inference and classification.

Most inventors, architect and designers have a well developed Spatial intelligence. This means that they can control space, color, line, shape and form. This intelligence allows for the capacity to visualize and transform information in the mind's eye. Having a "good sense of direction in strange places" can indicate the presence of this intelligence.

A person who has a well developed Musical intelligence has a sharp understanding of tone, sound, melody, timbre and other music concepts. They are very adept at transforming, creating, and recognizing music.

Interpersonal intelligence is used when one is making decisions for or with a group. The understanding and sensitivity to other's is a characteristic of this intelligence. A well developed interpersonal intelligence allows for the ability to understanding people's motivations and reasoning behind them. This may include facial expressions, body language, or tone of voice.

The challenge of designing children's material

Since the nineteen fifties, there has been an upsurge of production of material focusing on children. Steven Heller, writer and art director writes, "Children have become more visible in society." In fact, most publishers are begging for part of the children's market by publishing a larger than usual amount of toys and entertaining materials.

From a graphic design standpoint, designing for children is an interesting challenge. Adults buy the merchandise that children consume and have a certain power over what is allowed and what is not. Designers are put in a new position. As the translators between the adult and the children's imagination. The thesis design application will need to play two important roles, appealing to the adult and the child.

Interpretive Research Matrix

Matrices are cross referencing tools useful in information gathering and analysis. A matrix was used to analyze research collected on Multiple Intelligences. The following matrix cross references the intelligences with learning materials and activities that can be used to stimulate them.

	MI Activities	Materials
Bodily kinesthetic (Building, acting, running, etc.)	hands on learning drama tactile activities sports	building tools costumes clay, manipulatives
Interpersonal (Teaching, interacting, etc.)	cooperative learning community involvement social gatherings peer tutoring	board games role playing games party supplies
Intrapersonal (Personalizing , reflecting, etc.)	individual instruction solitary meditation relaxation techniques	journals self checking materials inspirational texts
Linguistic (Talking, reading, etc.)	lectures group discussions writen assignments word games storytelling	journal books newspapers magnetic poetry
Logical mathematical (Measuring, quantifying, etc.)	brain teasers calculations critical thinking number games mental calculations	calculators science equipment counting beads / blocks
Musical (Composing, listening, etc.)	playing in a band learning instruments creating songs	audio recorder instruments music
Naturalist (Connecting to nature, etc.)	ecology animal / plant care gardening field trips camping	plants pets astronomy natural objects natural phenomena
Spatial (Seeing, visualizing, etc.)	visual presentations art activities critical thinking imagination games metaphor visualization	optical illusions overheads movies coloring books picture library

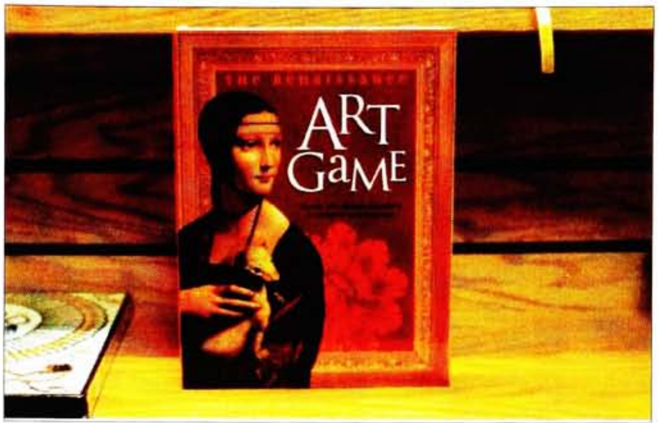
INFORMAL SURVEY OF EXISTING LEARNING KITS

The following photos were taken at Borders Books in Rochester New York. They show current, commercially sold learning kits.

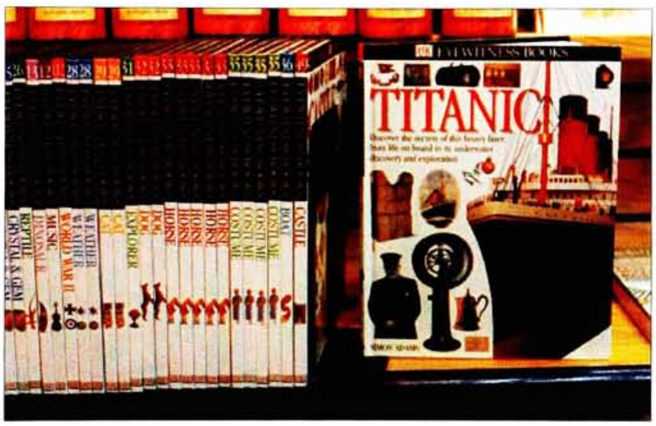
The French Language Pack

The Memory Kit

Ancient Civilizations Kit Series



The Renaissance Art Game



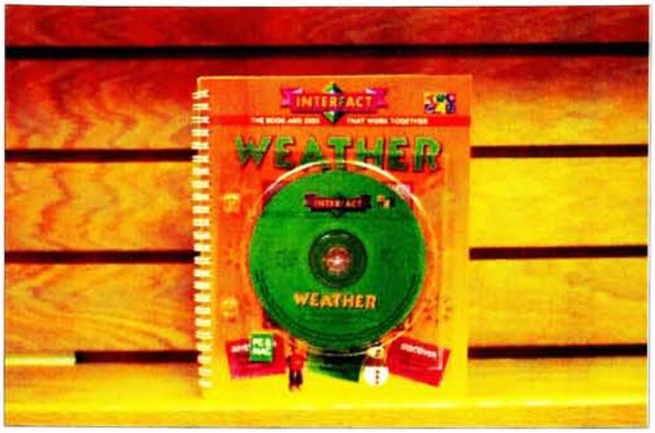
The Eyewitness Series

BOB Books Series

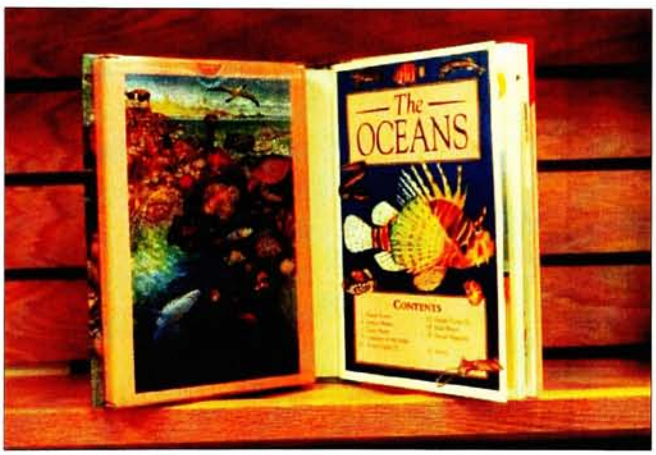
Kid Kits

Discovery Box Kit

Electronics Lab Kit

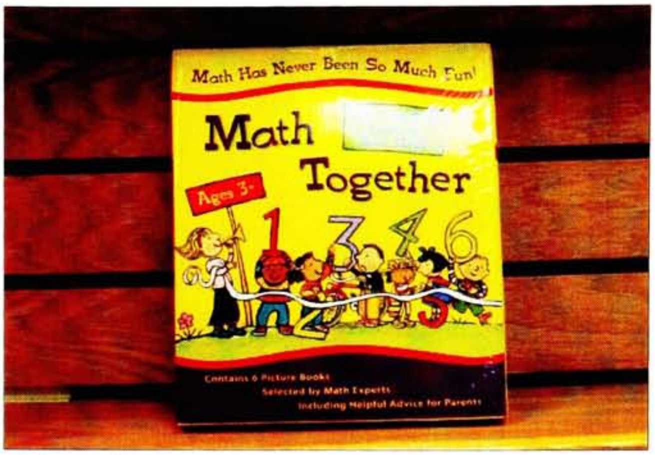


Interfact; Weather Book and CD



The Oceans Science Kit

Booktivity Book and Toy

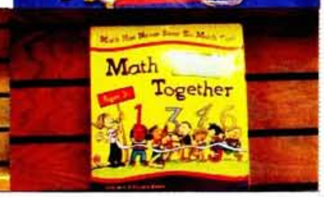


Math Together Kit

Brain Quest Cards

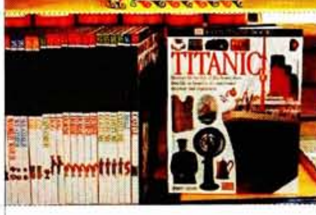
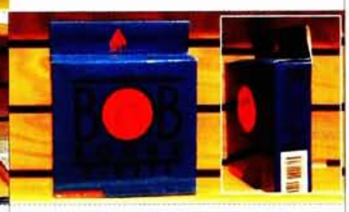
Comparative Research Matrix

The matrix shows how the teaching approaches employed by the kits utilize the eight intelligences.

	Science	Mathematics
Bodily Kinesthetic (building, acting, running, etc.)		
Interpersonal (teaching, interacting, etc.)		
Intrapersonal (personalizing , reflecting, etc.)		
Linguistic (talking, reading, etc.)	 	
Logical Mathematical (measuring, quantifying, etc.)		
Musical (composing, listening, etc.)		
Naturalist (connecting to nature, etc.)		
Spatial (seeing, visualizing etc.)		

Note, some kits fall into more than one intelligence category but were placed under one for research purposes.

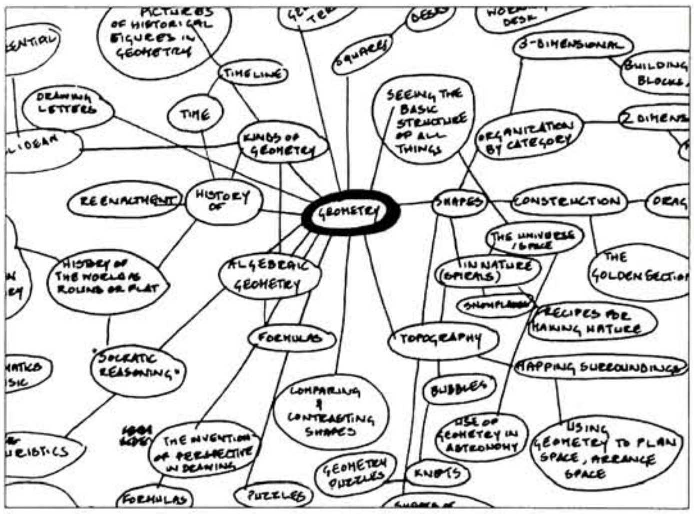
COMPARATIVE RESEARCH MATRIX *continued*

	Social Studies / History	English / Languages
Bodily Kinesthetic (building, acting, running, etc.)		
Interpersonal (teaching, interacting, etc.)		
Intrapersonal (personalizing , reflecting, etc.)		
Linguistic (talking, reading, etc.)		
Logical Mathematical (measuring, quantifying, etc.)		
Musical (composing, listening, etc.)		
Naturalist (connecting to nature, etc.)		
Spatial (seeing, visualizing etc.)		 

A MULTIPLE INTELLIGENCE GEOMETRY KIT

Geometry was chosen as a subject for the model because of its connection to graphic design.

The first step was to create content for the kit. The form that the design would takes follows logically from its content. A mind map was created to explore and then narrow the possible lessons that the geometry kit includes.

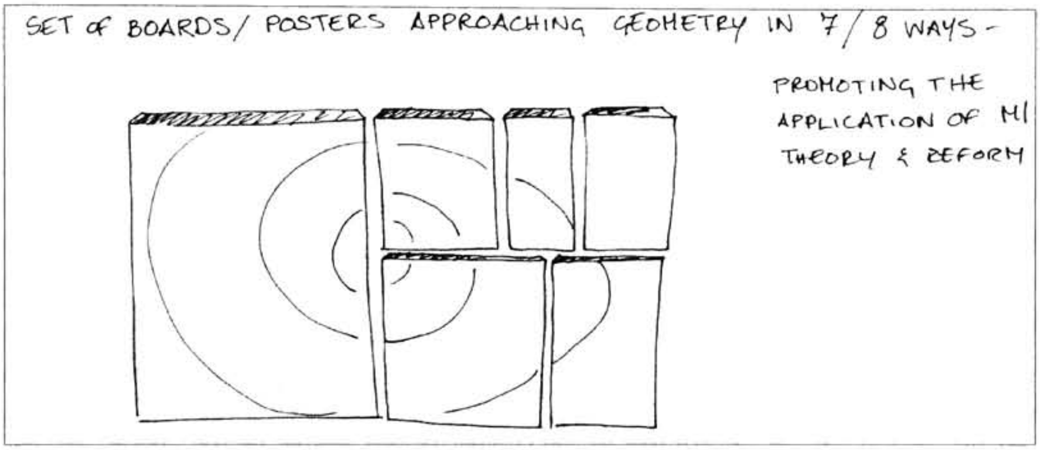


Preliminary

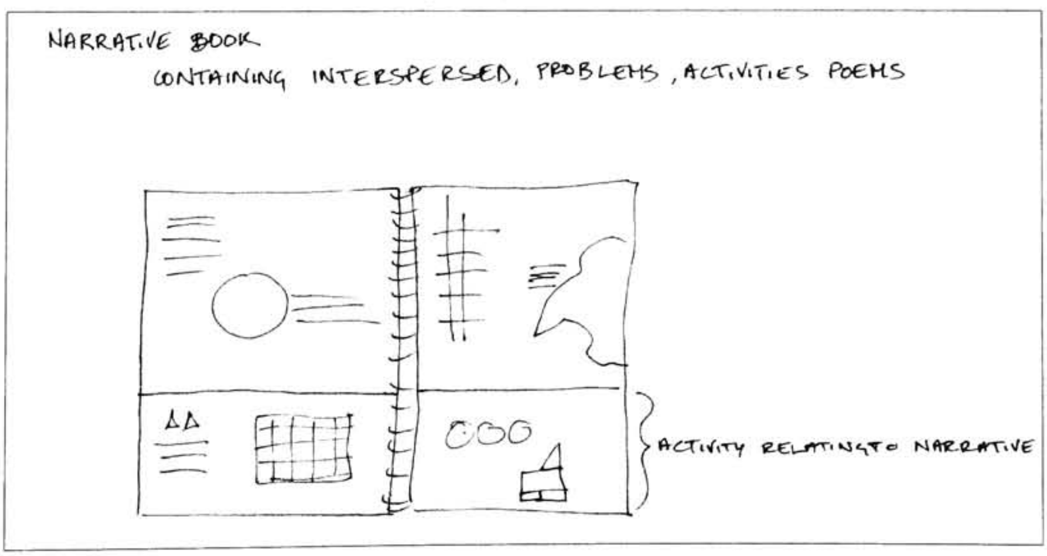
Conceptual sketches of learning material

Conceptual sketches were drawn first, in order to find an appropriate form for the thesis design application.

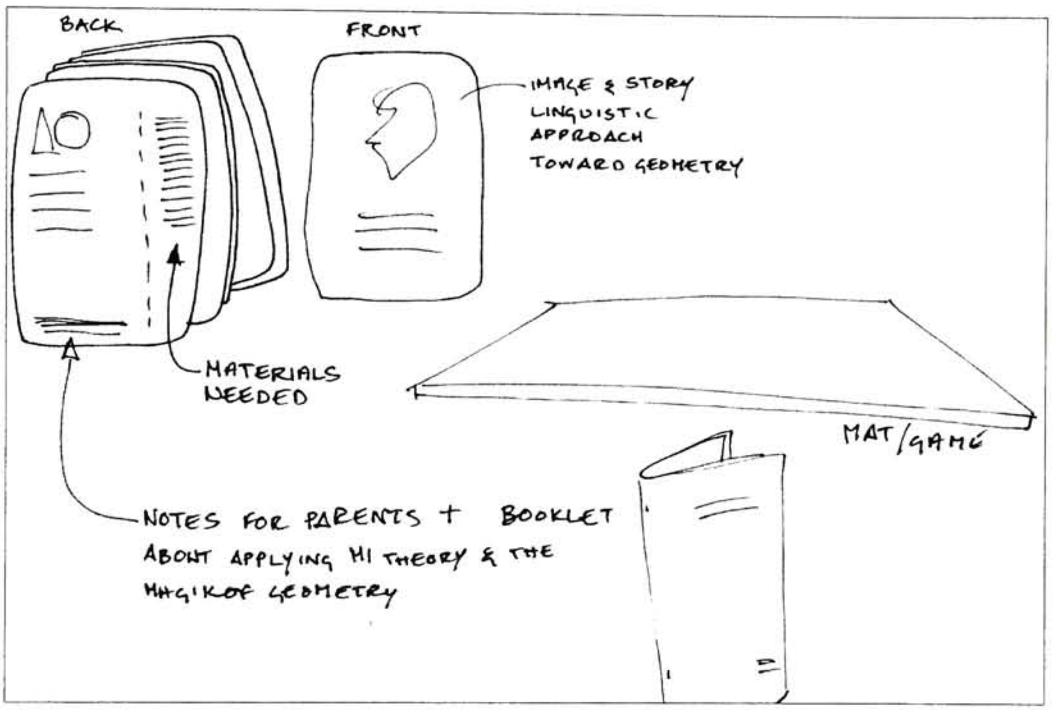
Below is a sketch of a set of posters intended for the school environment. They explain Multiple Intelligence Theory in two different ways, one explanation for children and another for adults to appreciate.



Another prilimanary sketch presents a narrative book with accompanying activities.



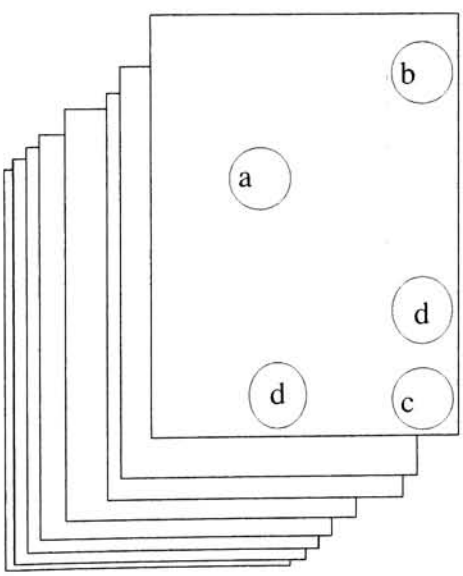
The third of three sketches is of a kit that includes a set of cards with activities, a booklet and other materials that could be used with the activities. Of the three, this was the most successful solution for the intended purpose.



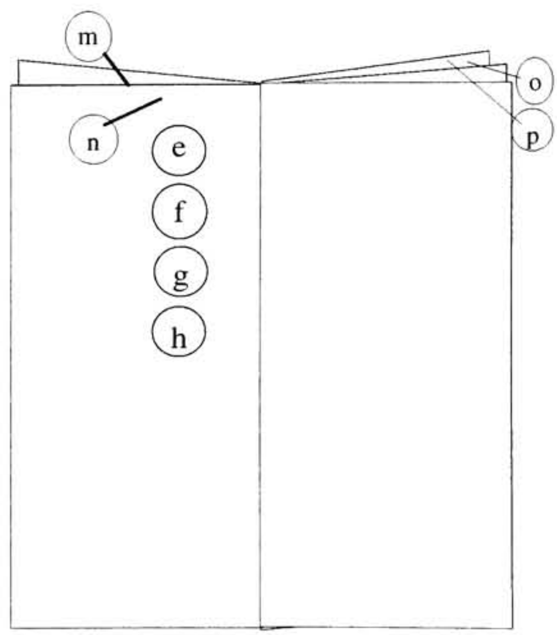
Intermediate
Thesis design application:
Activity Kit Content Exploration

Taking the concept sketch further, ideation was performed to determine the final content of the kit. The following is an example of the result of this process.

a. **Activities / geometry problems**
b. answers to problems (if applicable)
c. materials needed for excercises
d. instructions for excercises
e. an example of correct answer
f. **Explanation of intelligences (for children if possible)**
g. **Directions for adults on using the whole package**
h. bringing it into the classroom
i. using it with other material
j. using it at home w/kids
k. **Directions for adults on using individual activities**
l. independent learning
m. using it for cooperative learning
n. **Introduction to MI in the learning environment**
o. why this is important to introduce
p. **Assessing activities**
q. Observation of children



Activity Cards
quantity; 24



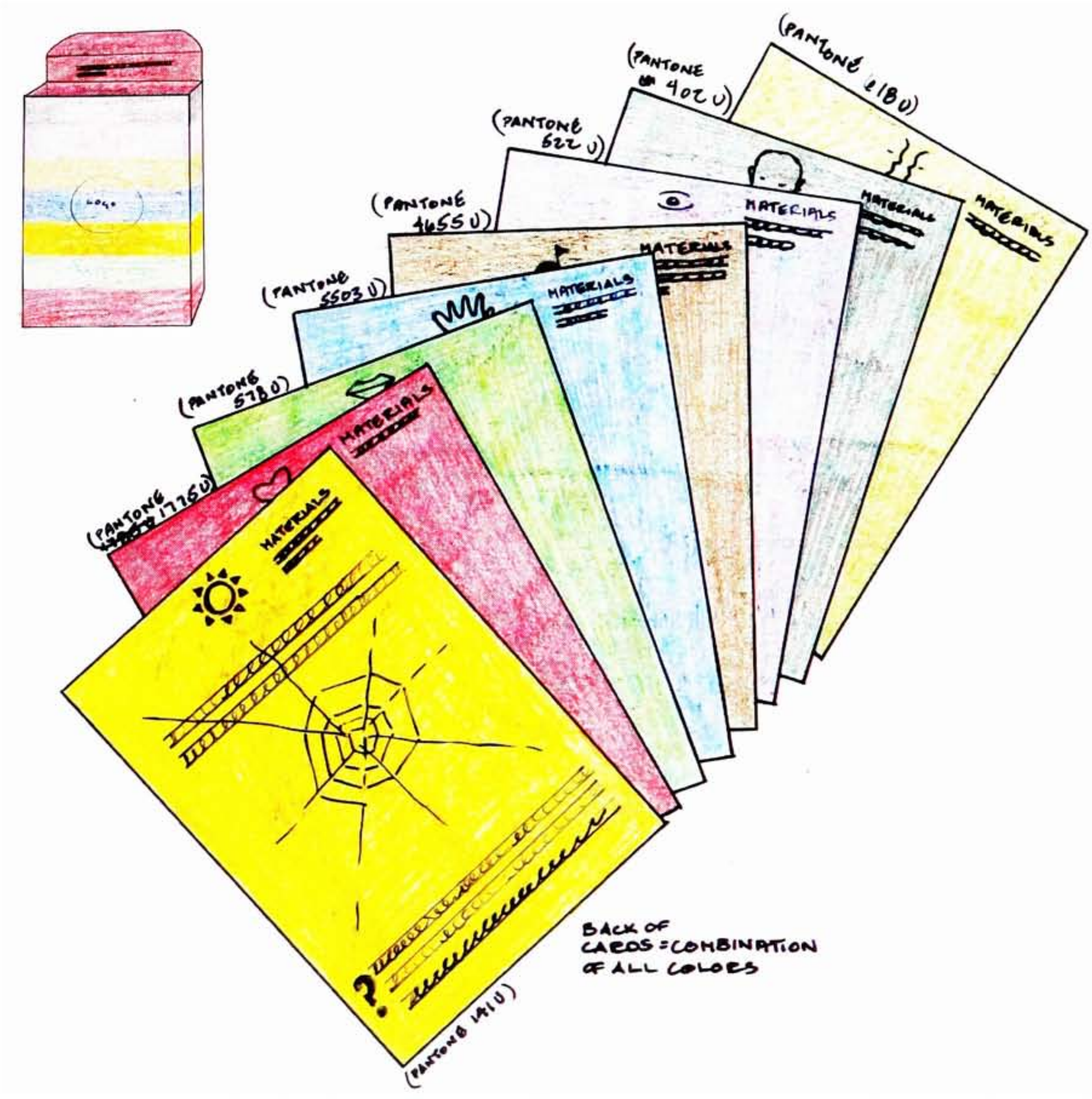
Activity Booklet

Final

Conceptual Sketches of Activity Cards

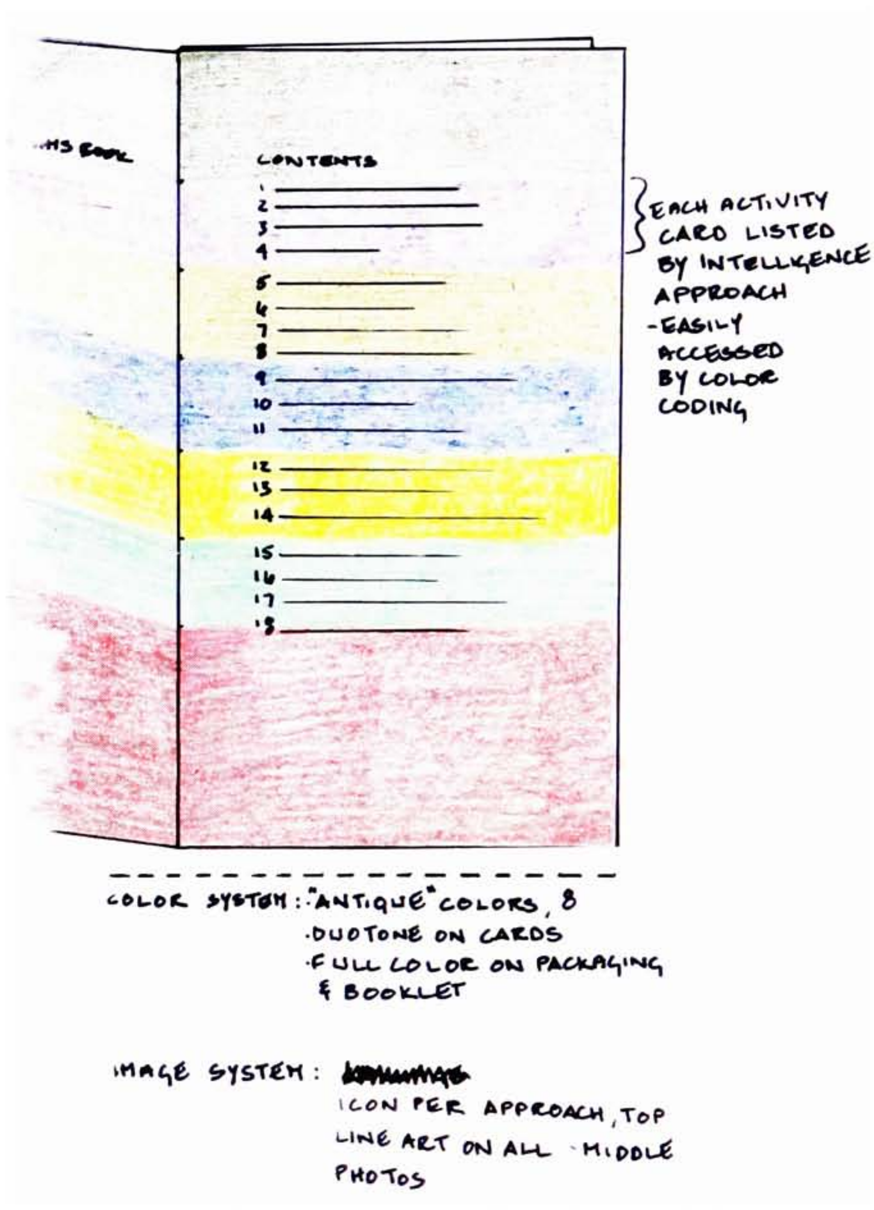
1a. Activity Cards and Packaging

Once the content was determined, design systems could be put into place. The following sketches experiment with language, spatial and color systems to be used for the thesis design application.



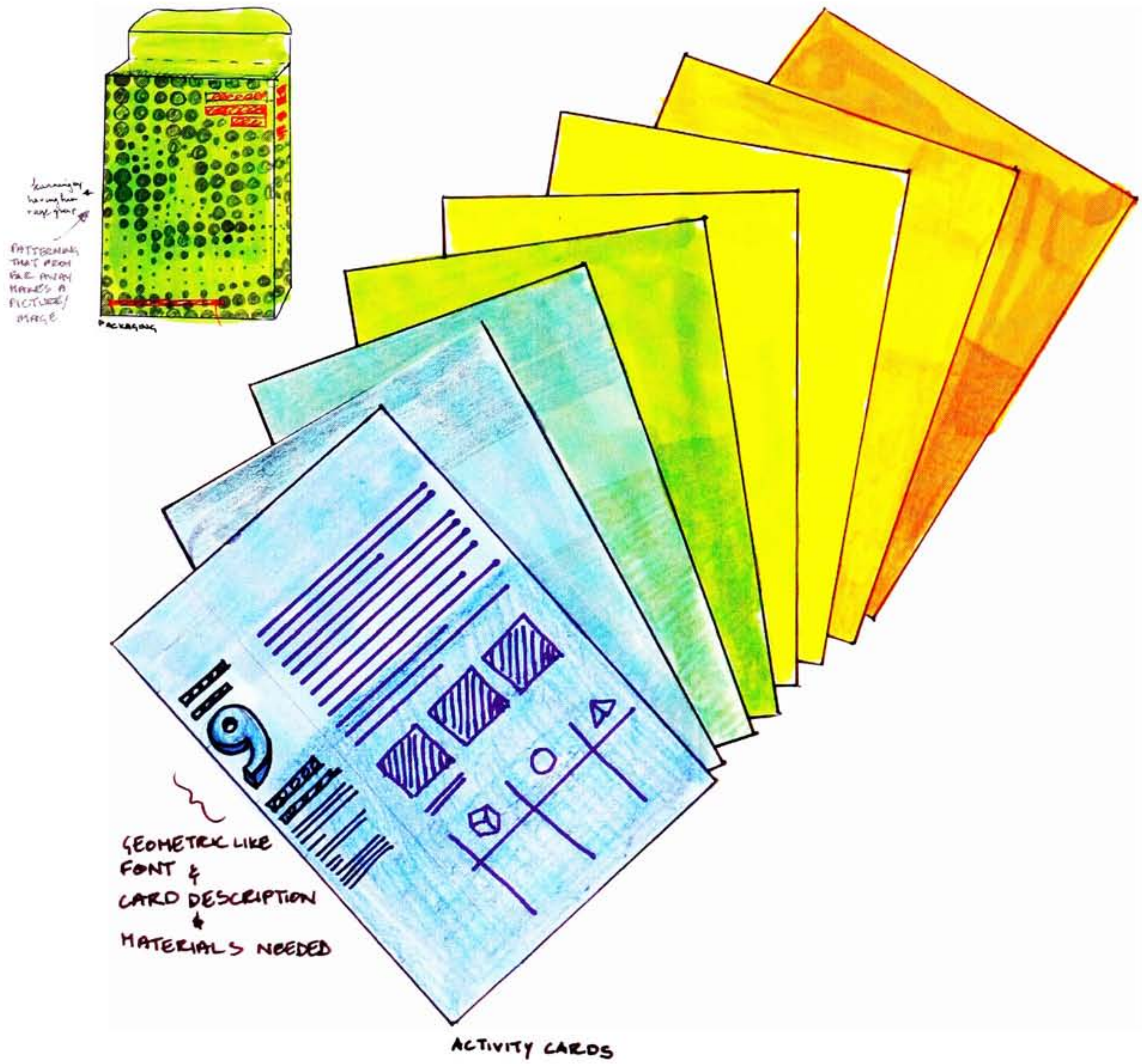
Conceptual Sketches

1B. BOOKLET



Conceptual Sketches

2a. Activity Cards and Packaging



Conceptual Sketches

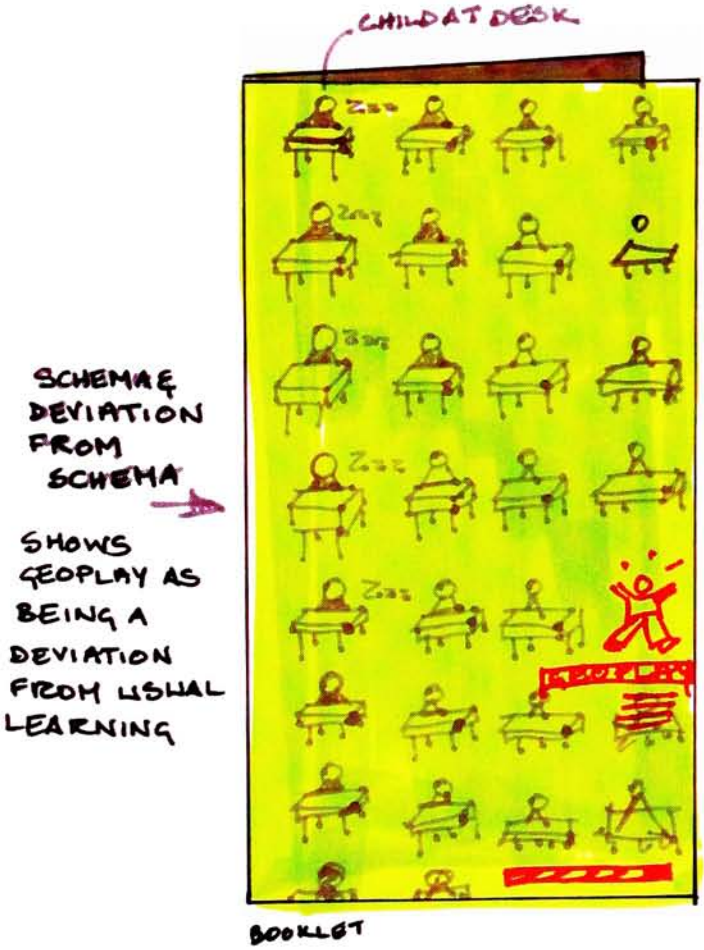
2b. Booklet

Conceptual Sketches

3a. Activity Cards and Packaging

CONCEPTUAL SKETCHES

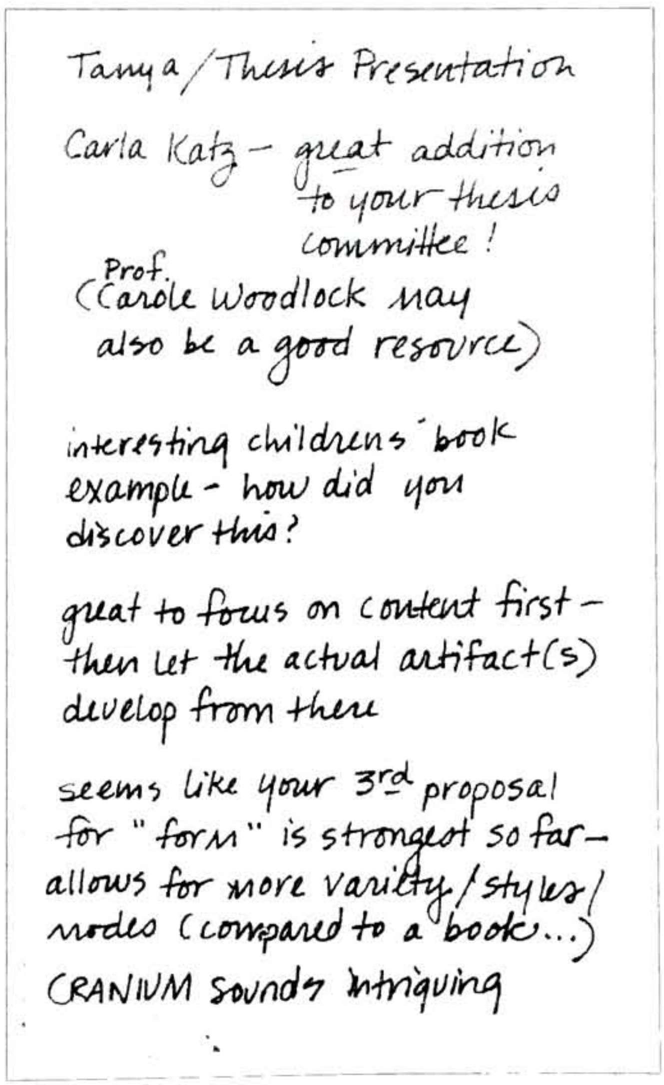
3B. BOOKLET



Presentation to Professors and Design Students

On February 1st 2001, a presentation was given to graphic design graduate students and professors, describing the current status of the thesis process. The research collected on Multiple Intelligence theory, as well as some conceptual sketches for the thesis design application was included in this presentation.

The feedback given during and after the presentation, in the form of questions, comments and discussion demonstrated an interest in the topic and agreement with the proposed responsibilities that designers have with instructional design. Below are comments concerning this presentation given by professor Deborah Beardslee to the designer in the form of an index card.



Tanya / Thesis Presentation

Carla Katz – great addition to your thesis committee!

(Prof. Carole Woodlock may also be a good resource)

interesting childrens' book example – how did you discover this?

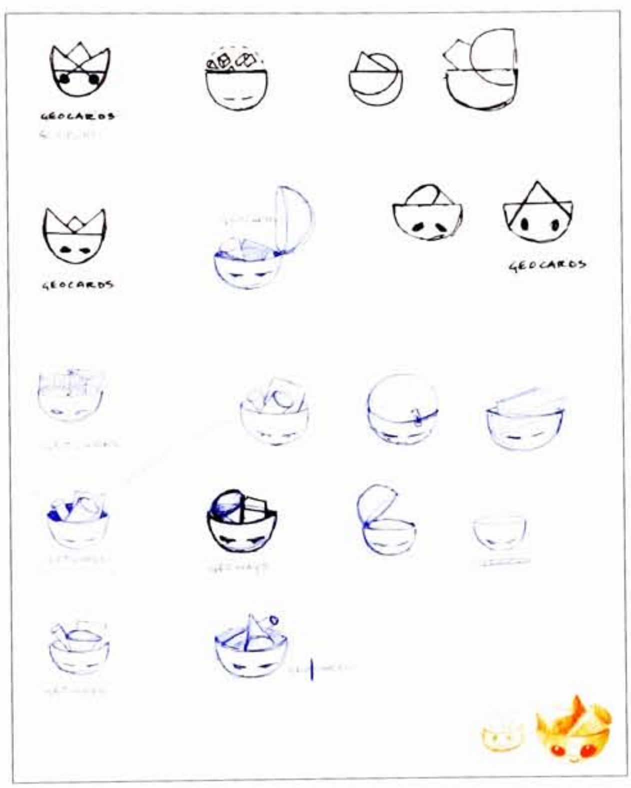
great to focus on content first – then let the actual artifact(s) develop from there

seems like your 3rd proposal for "form" is strongest so far – allows for more variety / styles / modes (compared to a book...)

CRANIUM sounds intriguing

IDENTITY DESIGN

Using the research information previously analyzed and collected, an appropriate identity had to be formed for the thesis design application. Below is the ideation for a logo and name for the instructional kit.



GEOPLAY

the geometry kit with multiple approaches

Instructional Design

To implement the design, geometry problems were compiled that approaching geometry from the perspective of each intelligence. The following represent one from each category.

Geometry using Bodily- Kinesthetic Intelligence

This section of cards have been designed to specifically involve the child through hands on learning. Using activities that include the manipulation of objects increases students retention.

Geometry using Logical Mathematical Intelligence

These utilize activities utilize critical thinking skills and include exercises such as calculating, comparing, quantifying and categorizing. Usually, only science and math classrooms incorporate this type of thinking.

Geometry using Naturalistic Intelligence

This intelligence benefits from using nature as a vehicle for learning. These activities use the natural world as the key to comprehending geometry. Most classrooms cut the child off from this most powerful source of inspiration.

Geometry using Linguistic Intelligence

Storytelling and word games are just two ways these cards stimulate linguistic intelligence. This intelligence is used extensively in schools. However, rarely is it used to teach mathematics.

Geometry using Visual Spatial Intelligence

Here geometry is taught through visual mental exercises, drawing and picture metaphors that use color cues, sketching and other visual strategies.

Geometry using Interpersonal intelligence

These group activities serve as a way to learn geometric concepts and benefit social learners. Some strategies include peer sharing, using the buddy system and other games.

Geometry using Intrapersonal Intelligence

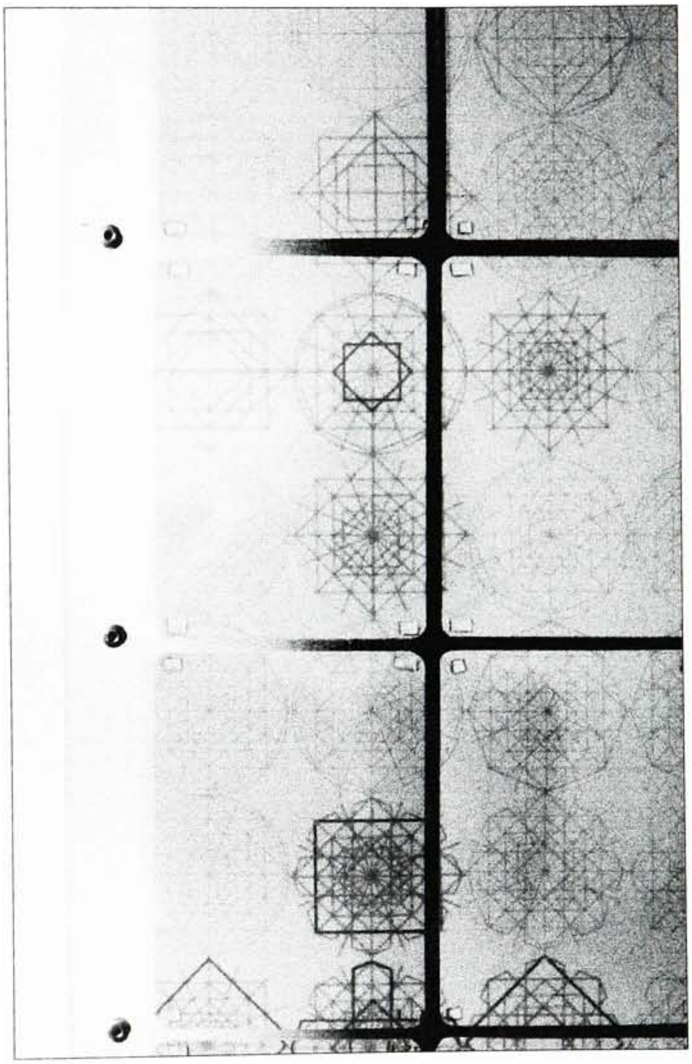
These revolve around self exploration and invention. They are exercises that are meant to be completed by individually and stimulate Intrapersonal intelligence. A journal is used extensively.

Geometry using Musical Intelligence

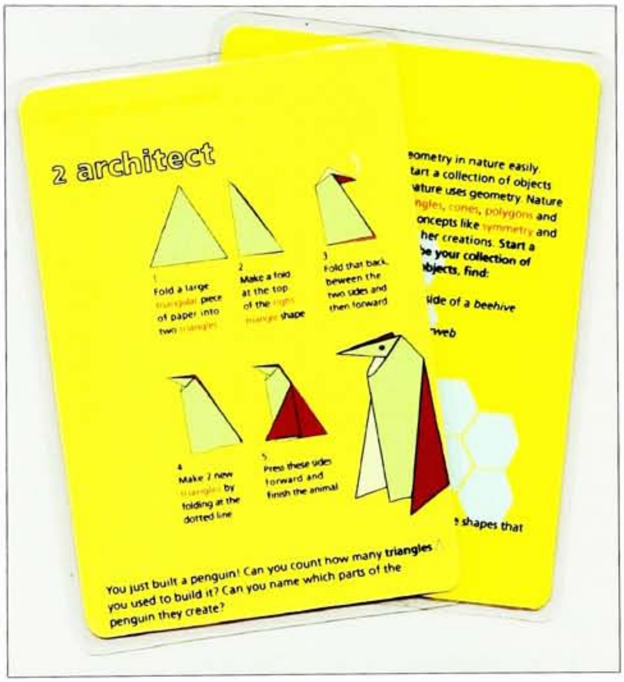
Geometry is explored through music composition, rhythm versus shape recognition and other sound oriented activities. A tape of recorded instructions should be part ofd the design but was not produced for this thesis project.

Puzzle Design

Taking advantage of the space on the back of the activity cards, a puzzle inspired by Islamic art was created. It is a challenge to Spatial intelligence and stimulates Intrapersonal intelligence. A parent or educator has the opportunity to introduce the child to the different ways cultures apply geometry to express their culture.



The plexiglas panel designed for exhibition at the Bevier Gallery allowed viewers to see the front and back of the activity cards. This is a close up of the assembled puzzle.



The above cards are two of a deck of twenty seven. The following pages present the entire deck.

How to Use this Kit

GEOPLAY activity cards will show you geometry in many exciting ways. Bring the pack to school, use it with your family, or just play with it yourself.

Use everything around you in the classroom or at home to help you solve these puzzles and games.

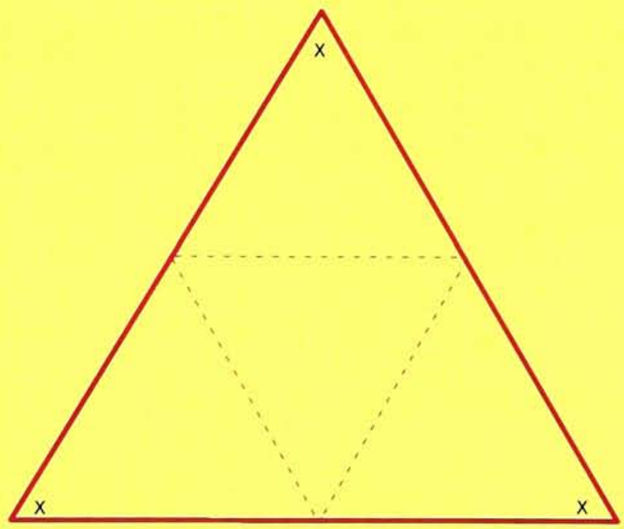
Geoplay cards are shown at actual size.

pencil · paper · scissors · journal

1 mechanic

Turn this triangle into a three dimensional triangle!! To put together this tetrahedron, photocopy or trace this shape on paper, fold on the dotted lines, tape the shape so that points "X" meet.

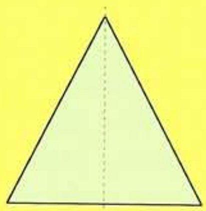
Hint: Fold the dotted lines first, then tape the shape.



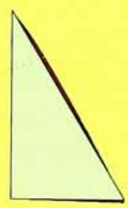
Too Easy? Try copying this shape bigger and putting it together. You are on your way to making an octahedron!

pencil · paper · scissors · journal

2 architect



1
Fold a large triangular piece of paper into two triangles



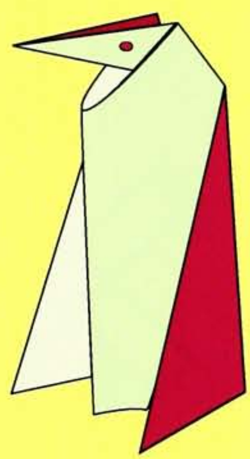
2
Make a fold at the top of the right triangle shape

3
Fold that back, between the two sides and then forward

Hint: Open the penguin after you folded the parts and count the triangles that are made from the creases.

4
Make 2 new triangles by folding at the dotted line

5
Press these sides forward and finish the animal



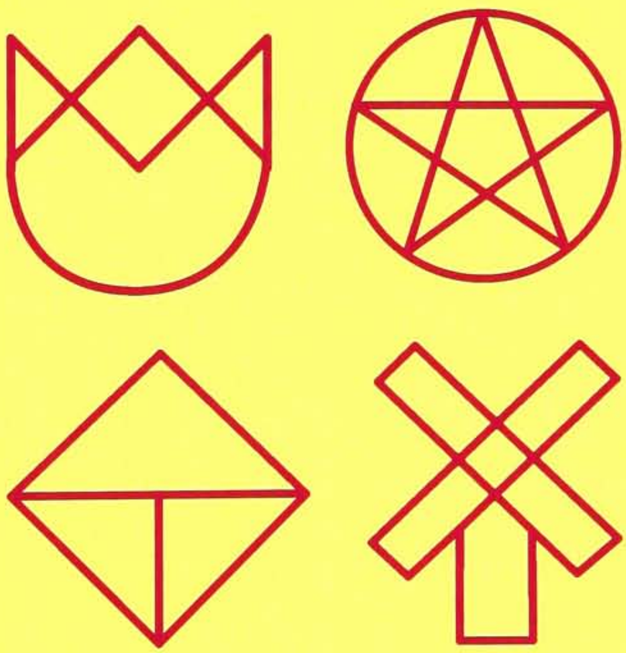
You just built a penguin! Can you count how many **triangles** △ you used to build it? Can you name which parts of the penguin they create?

fingers · imagination · pencil · journal

3 planner

Trace your finger along the lines in each puzzle. See where each line segment starts and ends. How many times does your finger have to leave the card to trace the shape? **How many line segments does each puzzle have?**

Hint: Unfold the penguin you made and count the triangles that are made from the creases.



Can you make a puzzle of your own using line segments?

pencil · paper · scissors · journal · yardstick ruler · string

4 surveyor

The ancient Egyptians didn't measure objects as we do today. They used ropes and sticks to make squares on the land they were measuring. Afterwards, they added the squares found the area (for example, six square units). In fact, the great pyramids were built this way. With string and tape, you can measure the perimeter around an object or the area inside it! **Can you find the perimeter and area of your desk using the string?**

Hint: How much string do you need to go once around your desk?

pencil · paper · scissors · journal

5 peace maker

1
Fold the paper in half

2
Fold four triangles out of the rectangle.

3
Fold one back and the other forward.

Hint: An origami book could teach you to fold the paper correctly.

4
Open the bottom with your finger and fold left and right points together

5
Crease front left and right edges to the center, then back out and pull up bottom point to produce shape shown next

6
Repeat it for the backside

7
open both sides along the middle

8
fold the right flap to the left

9
Fold the bottom point up to make a beak

10
Fold the wings down and blow into the bottom of the shape

pencil · paper · scissors · journal

6 creator

Snowflakes are ice crystals that have six sides. There are many different kinds, but all are hexagons. Make two six sided snowflakes. **How similar yours are to the ones that occur in nature?**

1
Start with a square piece of paper

2
Fold it into two triangles into it

3
Do it again

Hint: Open the paper after you folded the parts and count the triangles that are made from the creases.

4
Fold this one into thirds, one to the front and one to the back

5
Cut any pattern you want to, see the dotted lines if you are stuck

The water that makes up snowflakes freezes together in geometric shapes. Find a photograph of a real snowflake. How does your snowflake look like real snowflakes?

journal · pencil · shoebox

7 collector

You can find geometry in nature easily. See if you can start a collection of objects that show how nature uses geometry. Nature uses spirals, rectangles, cones, polygons and other geometric concepts like symmetry and glide symmetry in her creations. **Start a shoebox that will be your collection of natural geometric objects, find:**

Hint: Check your back yard in summer, or your mom's craft box.

· photograph of the inside of a *beehive*

· photograph of a *spiderweb*

· a *pinecone*

· a *seashell*

· a *sunflower*

· a *daisy* or *lilac leaf*

· *grapes* and their *leaves*

Write two sentences about the shapes that make up your objects.

journal · pencil · mirror

8 observer

A line of symmetry is an invisible line where the left and right sides can be divided into approximate mirror images of each other. The right edge of this card is a line of symmetry for the shape below. Can you put the right side of this card up to the mirror and see what object it is?

Hint: What do you have on the right and left side of your body?

Does your body have an invisible line of symmetry?

pencil . paper . scissors . journal

9 magician

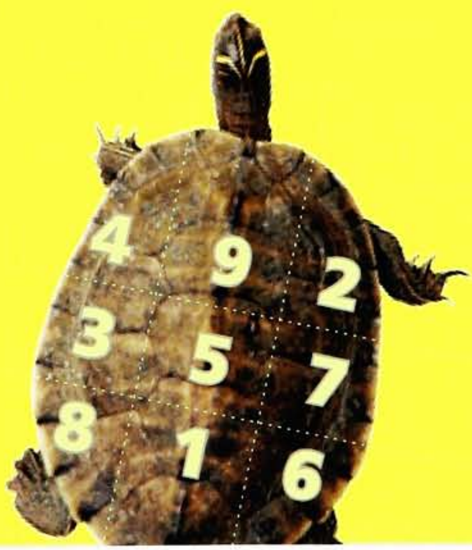
Magic squares have been around for over 3,000 years. They are descendants of the oldest known number mystery, the legend of Lo Shu, found in China. **What is the magic number that the turtle in the story is trying to show everyone?**

In ancient China, there was a huge flood. The people tried to offer some sacrifice to the river god of one of the flooding rivers, the 'Lo' river, to calm his anger. A turtle emerged from the river and walked around the sacrifice without touching it. The river god didn't accept the sacrifice until one time, a child noticed the curious figure on the turtle shell. After, they realized the correct amount of sacrifice to make.

Hint: What is the sum of the numbers in the 1st row? 2nd row? 3rd row?

What is the sum of the numbers in the first column? 2nd column? 3rd column?

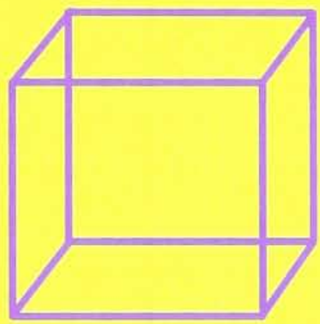
What is the sum of the numbers on one diagonal? The other



pen · three dimensional shapes · scissors · journal

10 inventor

The first shape has eight corners, six faces and twelve edges.



Hint: Think of the great monuments of ancient Egypt!

What kind of three dimensional shape has a square bottom, eight edges, five corners and five faces?

pencil · 3 dimensional shapes · journal

11 organizer

One way scientists learn about things is by putting them in categories. Learn more about basic shapes and these everyday objects by categorizing them.
Find a way to organize these objects into categories.

box of tissues

Hint: Put the objects together by the amount of corners or by the number of sides or shape.

drum

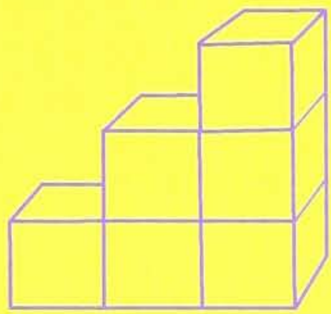
block

Make a list of other objects that you use every day. Which have geometrical shapes?

pencil · paper · three dimensional shapes · journal

12 problem solver

These stairs below are made of cubes.



Hint:
Find out how many cubes the first stair diagram has.

How many cubes would be needed to make the steps nine steps high? **When it is nine steps high, how many corners, edges and faces do the stairs have as a whole?**

journal · pen · dictionary

13 decoder

Can you unscramble the geometry terms in this story?

Hint: Try reorganizing the letters on a separate sheet of paper.

My math teacher said my box of toys is a many sided closed figure called a plgonyo. The toys don't fall out because there are desis that enclose everything. It is longer than a cube, but it is just like a nrtaglecaru mpsri. One of my favorite toys is a flat three sided light catcher! When I drew a picture of it I used three neli sgntmese to draw the sides. It looks so real, it almost came alive! I drew a euilqaralet triangle and used a protractor to draw angles and a lerur to measure the sides. This gltienar reflects light on all three corners and sparkles by the window!

journal · pen

14 storyteller

An Indian emperor was so fascinated by the game of chess that he said he would give the inventor any reward he wanted. The crafty inventor said that he would like one grain of wheat for the first square on his chessboard, two for the next, four for the next and so on. This is known as a geometric progression. **Can you find out how many grains the clever man has all together? Try finding an answer for this *64* square chess board.**

Hint: You may need a calculator to help you.

1	2	3	4	5	6	7	8
9	10	11	12	13	14	15	16
17	18	19	20	21	22	23	24
25	26	27	28	29	30	31	32
33	34	35	36	37	38	39	40
41	42	43	44	45	46	47	48
49	50	51	52	53	54	55	56
57	58	59	60	61	62	63	64

journal · pen · dictionary

15 writer

The poem below is about symmetry. Read it and use it as a guide to write your own. **Write a poem that describes a cube, cylinder, sphere or a triangular prism?**

Symmetry
by Mike Szewczyk

We each have a side left.
We each have a side right.
We use symmetrical eyes
To give us clearer sight.

We stroll with symmetrical legs
That stand on either side
Or help us pedal bike pedals
When we choose to ride.

We are blessed with a left hand
And one that's symmetrical right
That keeps us balanced at the desk
When we're asked to write.

Now our nose is in the middle,
Smack dab on symmetry,
But it has two holy nostrils
For blowing after a sneeze.

Sweet symmetry gives form to me.
I can run a straight line in track,
But ours is between side to side
And not measured front to back.

pencil - journal - geometry words

16 poet

Poets are inspired by geometry. In fact, there is a kind of poem called a Diamonte because of it's shape. The Diamonte is a kind of poem like the Cinquain. Diamonte means diamond which, in geometric terms can be two triangles or two triangular prisms placed together. **Can you create a poem in this form or create a new form of poetry that is inspired by geometric shapes?** Here is an example:

Hint:
Line 1:
Noun about geometry
Line 2:
Two Adjectives
Line 3:
Three 'ing words
Line 4:
Four words about geometry
Line 5:
Three 'ing words
Line 6:
Two adjectives
Line 7:
Synonym for geometry

Day
Bright, light
Waking, playing, eating
Sun, clouds, moon, stars
Resting, sleeping, dreaming
Dark, black
Night

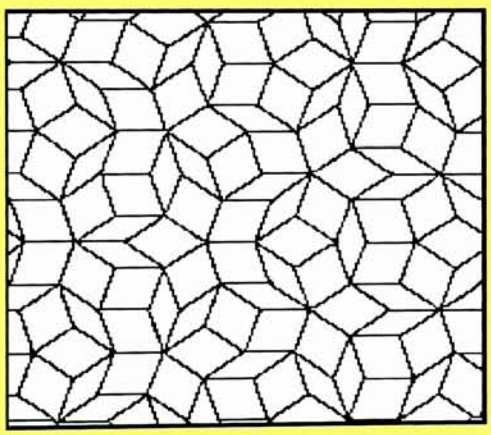
By Jason L.

pencil · journal · geometry words

17 illustrator

Geometry is an influence on art. In fact, some of the most prominent artists were mathematicians first. How can you combine triangles, squares, hexagons, trapezoids and rhombuses to form patterns on a flat plane (like a painting). **Use the example below and create a pattern that leaves no gaps.**

Hint: The shapes below will tile without gaps!
hexagon
square
rhombus
trapezoid
triangle



1. Which shapes fit together easily?
2. Which patterns could be repeated over and over again in the plane?
3. What shapes fit together using only one type of block?
4. What shapes fit together using two blocks that are different?

pencil · journal · stencils of geometric figures

18 artist

Can you transform geometric shapes into animals?

Hint:
Start with the shapes below!
hexagon
square
rhombus
trapezoid
triangle

M.C. Escher

markers · journal · template with geometric figures · tracing paper

19 drafter

Maps use lines and line segments to convey pathways. Mazes are maps too, but are more fun to get lost in! **Find your way out of this geometric shape? Can you make a maze like this or map the inside of your house with line segments?**

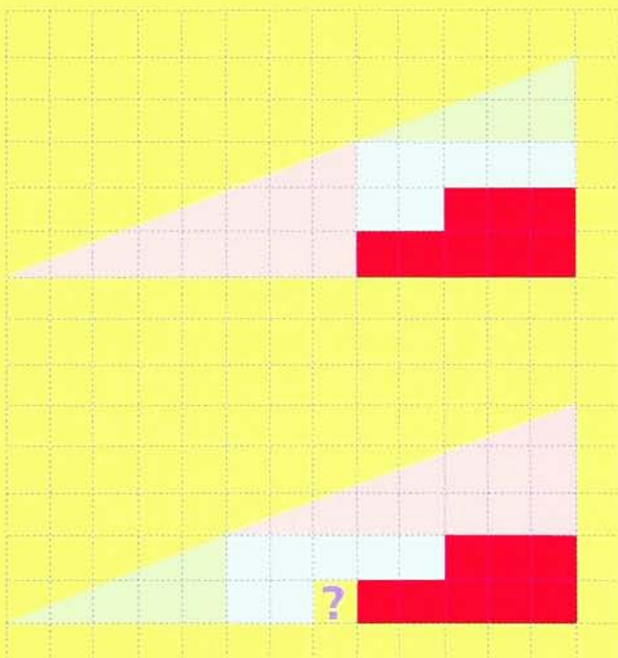
Hint: Use every line as a wall and every angle as a corner!

pencil · loose paper · journal

20 genius

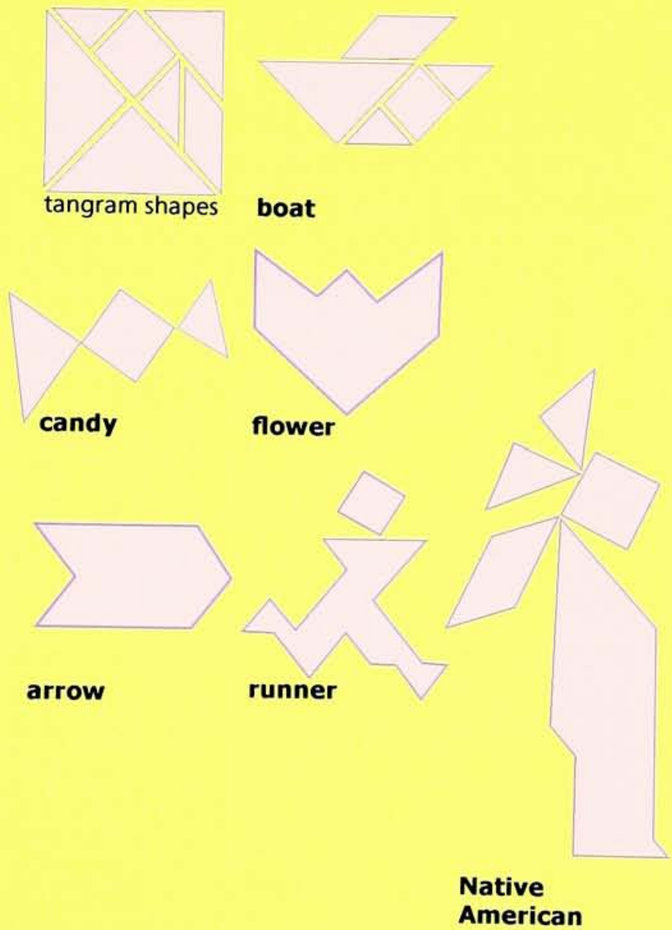
These two triangles are exactly the same except for one thing! **Why is there the extra space on the triangle below? How can this be true?**

Hint: Imagine moving the shapes of the first triangle in your mind. Try to draw the shapes on graph paper to test answers to the puzzle!



pencil · paper · journal · tangram pieces

21 sculptor



Hint: Start with the boat, to see how it is done.

partner · two dimensional shapes · envelope

22 prankster

Find a neighbor. Put a two dimensional shape into an envelope and write the name of the shape on the outside. **Stick it on your partner's back and have him or her guess what shape it is with fifteen questions. If they get it, add one trick! Have him or her ask the questions that are listed here and you can only say *yes* or *no*.**

Hint: A dictionary may be handy.

1. Do I have 2 points?
2. Do I have 1 angle?
3. Do I have 2 angles?
4. Am I two or three dimensional?
5. Do I have eight "sides"?
6. Do I have 1 side?
7. Do I have 2 sides?
8. Are any of my sides parallel?
9. Are any of my angles more than 90 degrees?
10. Are any of my angles less than 90 degrees?
11. Are any of my lines identical in length?
12. Are any of my angles identical?
13. Are all of my angles identical?
14. Are all of my lines identical?
15. Are all of my lines parallel?

partner · pattern shapes (triangle, rhombus, and trapezoid)

23 partner

Find a partner and play this geometry game. Each player covers part of the shape below with one of the flat pattern shapes. Say the name of the shape aloud before putting it down. Each color must be used at least once. Each block must touch another on at least one side. Continue until the shape is totally covered with pattern blocks. **The winner is the one to place the last block.**

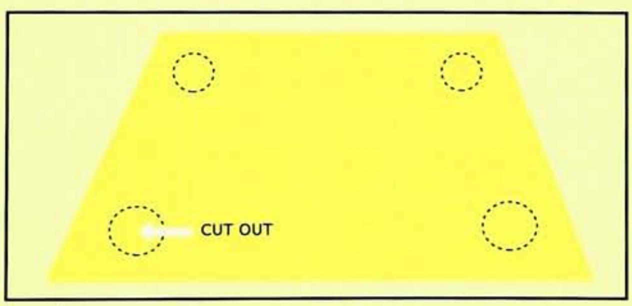
Hint:
Do your best!

ruler · partner · marbles · markers · walled boxes · dice

24 shooter

The game of Quads is played by four people, using a four-sided polygon and four marbles. Inside a short-walled box (for example, the lid of a Xerox paper carton), draw one of the following quadrilaterals: diamond, parallelogram, rhombus or a trapezoid. Cut a small, round hole about an inch in from each of the four vertices. Each player places one of his or her marbles in the shape and tries to bounce other people's marbles into the holes. When they do, the shooter asks the person they are playing against a question about geometry. If they get the answer wrong they lose their turn! Roll a die for who shoots first. The person who has the last marbles in the quadrilateral wins. Make the playing field as complex as you like, using geometric shapes.

Hint:
Brush up on the traditional game of marbles!



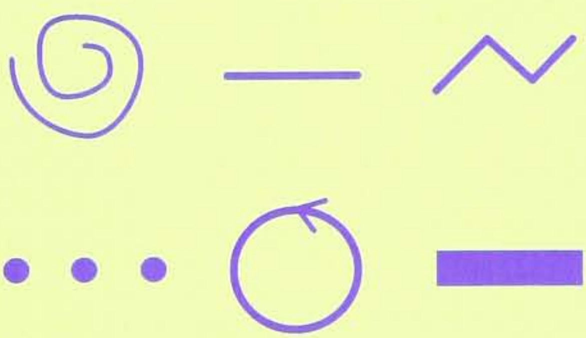
box top

a tape with your favorite song · tape recorder · journal · pen

25 composer

Composers write music with symbols. Sometimes composers use other shapes to describe what music sounds like. The pitch, rhythm, and speed. Create your own way of writing music using what you know about geometric shapes. Draw the shapes to look like your favorite song. How would a pointy pyramid sound like compared to a cube? **Use the following shapes and lines to describe your favorite piece of music.**

Hint:
Find a picture of musical notes as a guide!

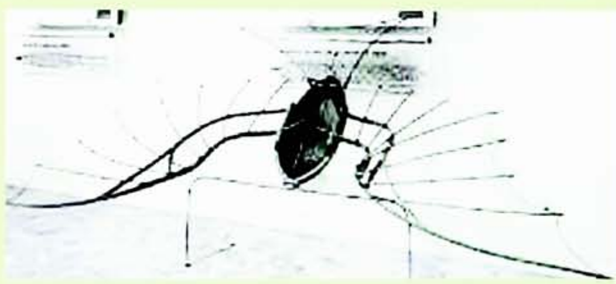


In your journal, explain the reasons for choosing the shapes that you did.

ruler · colored pencils · markers · markers · three and two dimensional shapes · journal ruler

26 thinker

Leonardo Da Vinci was called the Father of Invention! Out of his imaginative thoughts came great new objects. Some of them were flying machines. **Can you use three dimensional shapes to create an invention that will make people's lives better? Here is the Flying Boat Da Vinci invented.**



Hint: Find information about the inventor!

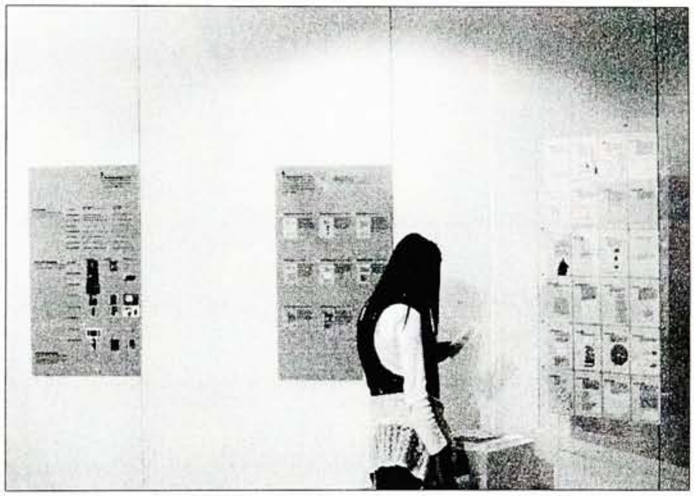
When you are done answer these questions:

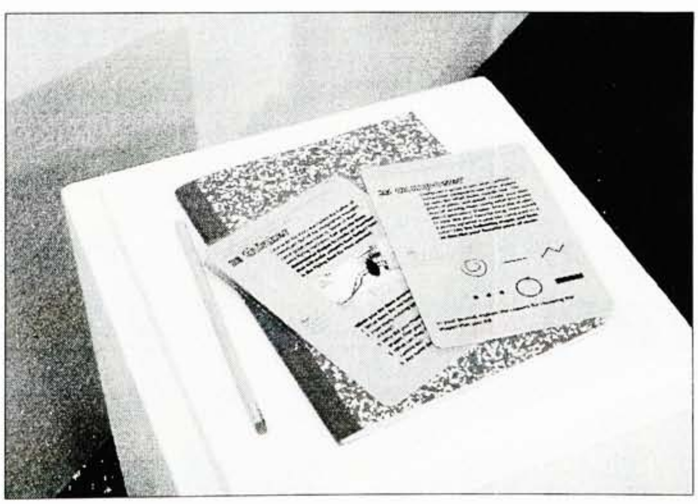
1. What does the machine do?
2. How many moving geometric parts does it have?
3. Why did you choose the geometric shapes that you did?
5. What can they do that other shapes cannot do?
5. Are some decoration?

BEVIER GALLERY EXHIBIT

The thesis process and design application was exhibited at the Bevier Gallery on April 7, 2001. The presentation was designed for the general public. Basic information was provided, educating the public of Howard Gardner's work and of the Geoplay cards that resulted from the thesis process.

The exhibit was designed to include background information, key research information and design principles that were key to the design application. This was displayed on 26 by 36 full color panels. The Geoplay cards were presented behind two glass panels for best viewing. The laminated cards could then be seen from the front and back. To add context to the project, a pedestal was provided with a third grade journal and two loose cards.





Feedback from children

To recieve feedback from the target audience, two interviews were held with children of the desired age group. The following are key points in the discussions held after the children were allowed to play with the cards.

Do you think you could play with these cards by yourself if you wanted to?

> **Joli, 8;** "Yeah, they would be good to learn at home."
> **Alexi, 8;** "If I had instructions, yeah."
> **Issah, 9;** "I'd have to ask my mom sometimes but I like them."

Alexi Irvine Irvine

Are the activities fun?

> **Joli, 8;** "I like all the colors and names. The one where you go outside is the most fun."
> **Alexi, 8;** "uh-huh, it's like a toy you can learn from."
> **Issah, 9;** "I can carry them in my bag and play with 'em anywhere. I think that's the most fun."

Joli Irvine

Do you want to learn math this way? Would you want your teacher to use these cards as part of her teaching you?

> **Joli, 8;** "I wish my books were like this."
> **Alexi, 8;** "we use workbooks and have to fill stuff out. This would be more fun."
> **Issah, 9;** "Some are hard, but yeah."

General Feedback

Another important source of feedback was from professors and other design professionals. The following is a summary of comments from these others.

Professor R. Roger Remington gave positive feedback and suggested bringing the project further by publishing it. With a group consisting of educators the Geoplay cards would be well received. As a whole, he thought the proposal was well done, and the whole project was an interesting, and urgent topic to address.

Joel Katz, a design professional, that came to speak at the Rochester Institute of Technology, gave positive feedback by suggesting that the title font be changed from outline to solid. The feedback was applied to the cards included in this report.

The process of evaluation is dictated by the measurement of value compared to the initial goals and objectives. Three essential characteristics of an effective evaluation are; measurable goals, measurable achievements, and proposed improvements.

Initial Goals Versus Achievements

Thesis Planning Stage

As a whole, the thesis project could not exist without the systems planning that occurred. The resulting output of this stage provided a spine for the body of work to come. The goals and strategies list, planning diagram, and planning calendar were used extensively to keep focused and to see the whole project from beginning to end. It was an adjustable system that allowed for the addition and subtraction of elements according to feedback.

Thesis Research Stage

The goal of the research stage was to respond to the need for learning materials that incorporate advances in the study of intelligence. Collected research included children's material, learning kits and Howard Gardner's pivotal work in this area and was crucial in building a foundation for the thesis design application, which demonstrates one of the many positive consequences occurring from designers responding to current advances in psychology. The thesis research stage not only defined the role that graphic designers have, it proposed and defined one of many paths toward responding to the situation.

Discussions during committee meetings and interviews demonstrated positive results from designers crossing disciplines to achieve goals. The designer gained valuable information about psychology, education, while educators and others gained useful information on the role of a graphic designer.

Thesis design application Stage

Applying the research was another challenge with it's own goals and strategies. Instructional design should educate the user. The value of the design increases if the user's confidence in learning increases simultaneously. Geoplay cards have been created to stimulate the eight intelligences according to proven methods seen earlier. Many children, with their varied combinations of intelligences can utilize this kit to find their personal path to understanding geometry. Many reasons, such as the playful language system used and their portability add to the enjoyment of the learning experience. Designing with the understanding that education and entertainment can co-exist, Geoplay cards are a successful model of one of the many ways instructional design can stimulate learning *and* raise confidence in the child.

Thesis Dissemination Stage

An important goal of this thesis project was to educate the public of current psychology and the consequences this could have on education. The chance to exhibit was a successful step in the thesis process. With the help of Betsy Murkett at the Bevier gallery, this information was available to the public for two weeks.

A Plan for Improvement

Comparative Research Matrix

A comparison is made between sources of error in the main thesis Research stage and the methods that could have prevented them for future projects.

Stage	Area of Improvement	Possible Preventative Measures
Thesis Planning	· Planning Report (see Appendix A)	· validate report with others outside committee
Thesis Research Stage	· gather first hand information of Multiple Intelligence theory · use of education professionals	· Interview Howard Gardner or members of Project Zero · use more resource people in education
Thesis design application	· activity card design	· begin gathering geometry problems sooner
Thesis Evaluation Stage	· user evaluation	· use a classroom of children to evaluate activity cards · evaluate a teacher using kit in lesson plan

The completion of this thesis project has been a landmark experience. The concepts and problem solving tools involved will aid in greater success in many other graphic design and non-design related challenges. Future projects will benefit greatly from the design research and planning methods used here. As a whole it will continue to be a source of learning, inspiration and proud conversation.

A respected professor, Luvon Shepard, stated that the best part of teaching is seeing the student go beyond his or her own initial expectations. This work has done just this, pushing the designer's skills and desire to accept meaningful roles past the any point imagined.

Authoring skills - John Wakefield's definition of the skills needed to design effective learning materials. Elementary , Intermediate and Advanced authoring skills are the hierarchy or sequence describing his method for successful design.

"Constructivist classroom" - a learning environment that creates learning and under-standing beyond the use of repetition of facts and rote memorization.

Curriculum based learning material - materials mainly containing exercises promoting learning through repetition and or other memorization tasks, i.e.: textbooks, workbooks

Exploratory learning material - materials that promote learning through experimental means, i.e.: story books, computer software, puzzles etc.

Harvard Project Zero - is an educational research group developed by Howard Gardner who's mission is to understand and enhance learning, thinking, and creativity in the arts, as well as humanistic and scientific disciplines, at the individual and institutional levels.

Higher-order thinking skills - thinking that takes place in the higher-levels of the hierarchy of cognitive processing. A continuum of thinking skills, starting with knowledge-level thinking and moving eventually to evaluation-level of thinking. Critical / creative / constructive thinking is closely related to higher-order thinking; they are actually inseparable.

Ideation - a stage in systematic problem solving methodology. The process of finding optional ways to realize a definition, or generate various means for reaching a solution.

Learning kit- a collection of materials that combines tasks to approach the teaching of a certain theme or subject. Also called an instructional package.Also called and instructional kit.

Mindmap- a written technique used to document stream of conciousness brainstorming using one subject as a springboard to another.

Multiple Intelligence theory (MI theory) - a cognitive model of intelligence proposed in 1983 by Howard Gardner in the book *Frames of Mind.*

Books

1. Armstrong, Thomas. *Multiple Intelligences in the Classroom.* Virginia: Association for Supervision and Curriculum Development, 2000.

2. Calder, Clarence, R, Antan M. Elenor. *Techniques and Activities to Stimulate Verbal Learning*. The MacMillan company/ Collier-MacMillan Limited: London, 1970.

3. Dunn, Rita and Kenneth.*Teaching Students Through Their Individual Learning Style.* Reston Publishing Company: Virginia, 1978.

4. Gardner, Howard. *Art Mind and Brain; A Cognitive Approach to Creativity*. Basic Books Inc.: New York, 1982.

5. Gardner, Howard. *Frames of Mind*. Basic Books: New York,1983.

6. Gutloff, Karen. *Multiple Intelligence* . National Education of United States: New York, 1996.

7. Haggerty, Brian A. *Nurturing Intelligences: A guide to Multiple Intelligences Theory and Teaching*. Addison-Wesley Publishing company: New York, 1995.

8. Heller, Steven and Steven Guarnaccia. *Designing for Children: The Art of Graphic Design... Games, Television, Children's Books, Toys, Records, Magazines, Posters, Newspapers.* Watson-Guptill Publication: New York, 1994.

9. Kappraff, Jay. *Conections: the Geometric Bridge Between Art and Science*. New York: McGraw-Hill Inc., 1991.

10. Koberg, Don and Jim Bangall. *The Universal Traveler*. California: Crisp Publications, Inc., 1991.

11. Lazear, David G. *Multiple Intelligence Approach to Assessment*. Zephyr Press: New York, 1994.

12. Little, G. Wayne and Harland Sampson. *Visual Merchandising: Planning and Techniques, Second Edition*. Cincinnati: South-West Publishing Company, 1985.

Appendix

A. Thesis Proposal

B. Thesis Quarter Planning Calendars

C. Developing Textbooks That Teach

D. The Theoretical Basis For Multiple Intelligence Theory

E. The Relationship of Multiple Intelligence Theory to Other Intelligence Theories

F. Mathematics Guide with New York State Core Curriculum

G. How Instructional Packages Facilitate Academic Achievement

H. Examples of Instructional Packages

Appendix A

VISUAL COMMUNICATION AND INTELLIGENCE:

a study in designing for multiple perspectives

A Thesis plan for the Graduate Graphic Design Department of the Rochester Institute of Technology by Tanya Harding

A.2

DESIGNER
Tanya Harding
486 Manse Lane
Rochester NY 14625
671 5194
tjh@rochester.rr.com

ADVISOR
R. Roger Remington
Design Department
RIT
475 2658
rrrfad@rit.edu

COMMITTEE MEMBERS
William Finewood
Art Department
RIT
3421 Booth
475 5218
wrffaa@vmsimap.rit.edu

Steven Loar
Foundations Department
RIT
3402 Booth
475 6747
sclfaa@rit.edu

As Alexey Brodovitch puts it, "graphic designers need to keep their fingers on the pulse of the times." We must answer to advances in the world around us. Graphic Design has the power to enhance learning and increase mental stimulation. Advances in cognitive research and perception, in the past ten years, challenge graphic designers to reconsider how visual syntax affects the mind. Accepting this challenge is a designer's responsibility.

How should printed material be designed in order to maximize the ability to understand material?

How should typography, line and shape be treated and combined with what kind of content?

What historic or new design methods and processes need to be applied or adopted to create a perfect balance of design elements producing this specific effect?

Discoveries in cognitive science affect our culture tremendously, in the styles we use to teach children, create curricula and books, and in the ways we present or absorb information around us. The past decade of research has widened the understanding of intelligence and perception. One discovery shows us that, unlike the old model of intelligence, different people use varying abilities to absorb and understand information. Some understand information through visual / spatial intelligence, others may use motor / kinesthetic or logical / mathematical. Graphic designers, being concerned with shaping information, must reevaluate visual syntax and answer questions that get to the heart of communication.

Exploration is needed. We must seek ways visual elements can be organized and formed, to entertain, exercise, stimulate and facilitate understanding. Designers, because of their visual problem solving abilities, have an important responsibility to involve themselves in this search.

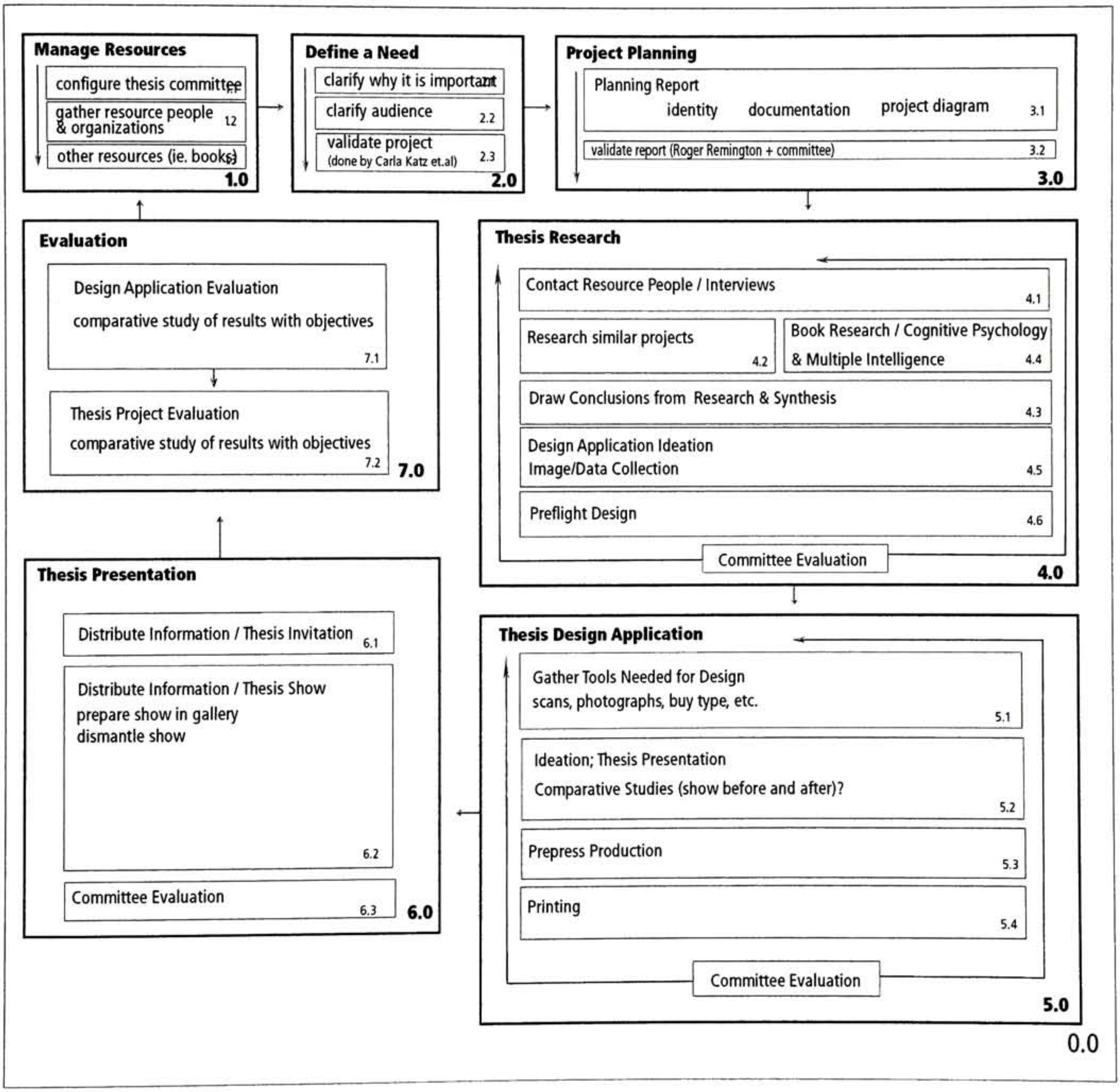
Breakthrough advances in cognitive science over the past ten years challenge visual communicators to reconsider how visual syntax and design affect intelligence and the comprehension of information. Rising to this challenge is a designer's responsibility. Being visual communicators, the exploration of audiences' responses to design and visual elements is one of the main keys to realizing the most effective methods.

The conclusions I develop will result in printed materials. They will represent my theories and prove our need as designers to adapt to new discoveries and "keep our fingers on the pulse of the times". The materials created will show the potentially powerful role that graphic design can have in exciting and sharpening the mind.

This exploration may be best informed with research on Multiple Intelligence Theory. It may include work by Deborah Sunbeck and Howard Gardner, among other pivotal scientists in the recent decade. Other topics to research may include book design, design methods, children's print material design, color, and formal visual design principles.

By developing a strong understanding of the research and the roles of visual elements, it will be possible to find relationships within the information. For example, the ways the mind reacts to design can be treated as a cause for how materials are designed. These connections can act as catalysts for theories, conclusions and seeds of methodology. Whether to design storybooks or educational materials, these theories may be crucial in developing methods for creating a thesis application. They could provide a list of goals the design should fulfill, or list specific properties that would create a successful solution, such as written content or typographic styles. Resulting theories could supply a basis for the development of usable methods for this thesis application and future projects.

VISUAL COMMUNICATION AND INTELLIGENCE: *a study in designing for multiple perspectives,* is a thesis project that will demonstrate how graphic design can be used to stimulate the intellect to the end that learning materials can be made more effective.


Manage Resources
configure thesis committee 1.1
gather resource people & organizations 1.2
other resources (ie. books) 1.3
1.0
Define a Need
clarify why it is important 2.1
clarify audience 2.2
validate project (done by Carla Katz et.al) 2.3
2.0
Project Planning
Planning Report
identity documentation project diagram 3.1
validate report (Roger Remington + committee) 3.2
3.0
Evaluation
Design Application Evaluation
comparative study of results with objectives 7.1
Thesis Project Evaluation
comparative study of results with objectives 7.2
7.0
Thesis Research
Contact Resource People / Interviews 4.1
Research similar projects 4.2
Book Research / Cognitive Psychology & Multiple Intelligence 4.4
Draw Conclusions from Research & Synthesis 4.3
Design Application Ideation
Image/Data Collection 4.5
Preflight Design 4.6
Committee Evaluation
4.0
Thesis Presentation
Distribute Information / Thesis Invitation 6.1
Distribute Information / Thesis Show
prepare show in gallery
dismantle show 6.2
Committee Evaluation 6.3
6.0
Thesis Design Application
Gather Tools Needed for Design
scans, photographs, buy type, etc. 5.1
Ideation; Thesis Presentation
Comparative Studies (show before and after)? 5.2
Prepress Production 5.3
Printing 5.4
Committee Evaluation
5.0
0.0

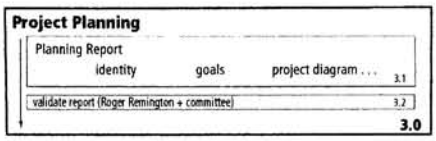
INPUT, PROCESSES AND OUTPUT

THESIS PLANNING 3.0

INPUT

- clarified and validated need for project
- thesis planning calendar
- preliminary research
- concept of a problem
- concept of surrounding situation
- concept of directions toward a solution

PROCESS



OUTPUT

- outlined plan for research
- focused problem to solve
- timeline
- project anatomy
- strategies for each phase in project anatomy
- goals for each phase of the project
- proposal document for committee members

INPUT, PROCESSES AND OUTPUT

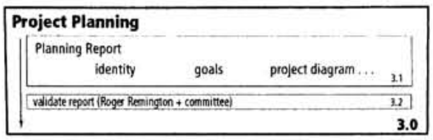
THESIS PLANNING 3.0

A.8

INPUT

clarified and validated need for project
thesis planning calendar
preliminary research
concept of a problem
concept of surrounding situation
concept of directions toward a solution

PROCESS



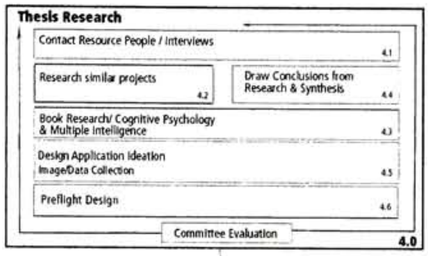
OUTPUT

outlined plan for research
focused problem to solve
timeline
project anatomy
strategies for each phase in project anatomy
goals for each phase of the project
proposal document for committee members

INPUT

- validation of a need to fullfil
- plan to fullfil the need
- sources (books, journals . . .)
- questions to answer
- goals objectives and strategies
- research thresholds
- assumptions
- preliminary interviews with resource people
- evaluation methods
- identity for the project

PROCESS



OUTPUT

- theories as to how to improve learning material
- methods of designing successful learning materials
- conclusions (ie; visual excercises and learning activities)
- visual principles to be be applied
- ideation for application
- layout for application

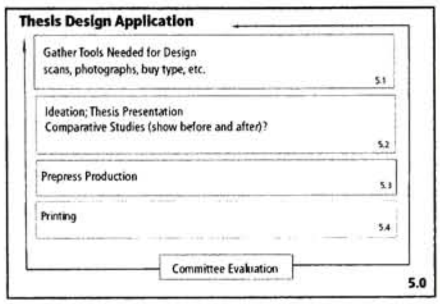
INPUT, PROCESSES AND OUTPUT

THESIS IMPLEMENTATION 5.0

INPUT

- thesis research material
- image selection/creation
- committee input
- design layout decisions
- written content for thesis application
- design theory to apply
- ideation based on design theory

PROCESS



OUTPUT

- thesis presentation materials
- thesis application

4.0 THESIS RESEARCH	OBJECTIVES	STRATEGIES
to *respond to the need* for learning materials that incorporate advances in the study of intelligence	· to *educate the public* on the new pluralistic definition of intelligence and the consequences of this theory for learning	· by defining intelligence as many abilities and ways of understanding · by researching and documenting different learning styles and intelligences
	· to *demonstrate positive consequences* occurring from graphic design responding to situations outside of itself	· by designing learning material that is based on Multiple Intelligence Theory · by interviewing and researching across disciplines · by documenting how a designer's use of visual syntax can play a large role in the success or failure of learning materials

4.0 DESIGN CONTENT	OBJECTIVES	STRATEGIES
to *educate and raise a viewer's confidence* in learning	· to design visual and written content that explains different learning styles	· by clarifying the goals of learning materials and, more specifically, the goal of the thesis application
		· by, for example, creating 7 materials (books, cards. . .)that explains one concept in 7 different ways
	· to *demonstrate at least one method* graphic designers can use to facilitate children's learning	· by providing exercises for each individual intelligence or learning style
		· by providing a test that pinpoints which intelligence the viewer uses most or least

5.0 THESIS DESIGN APPLICATION	OBJECTIVE	STRATEGIES
to *provide a successful design solution* that educates and is inclusive of new advances in the study of intelligence	· to *facilitate and unify* children's learning, providing an easier way for them to access information through a variety of means	· by involving more than one academic subject in a lesson or activity (by using drawing to teach anatomy for example)
		· by explaining material in ways that different intelligences can understand
	· to *provide a reference* or example for future designers	· by archiving a written document and design piece that exhibits research and theories
		· by showing research and implementation in an exhibit

6.0 THESIS EVALUATION	OBJECTIVES	STRATEGIES
to *evaluate the success* of the thesis process as a whole and it's parts	· to list ways to improve the research and design process in my future	· by compiling "sources of error" log at he end of the thesis process
		· by creating a matrix of successes, failures and thesis phases
	· to assess the successes of the design application itself	· by documenting outside opinions from sources such as the thesis committee

2000 CALENDAR

Sept.
- 1 Labor Day
- 22 first day of Autumn

Oct.
- 29 daylight savings ends
- 31 Halloween

Nov.
- 7 election day
- 23 thanksgiving

Dec.
- 7 rememberance day
- 21 first day of winter
- 25 Christmas

Jan.
- 1 new year day

Feb.

Mar.
- 17 St. Patrick's day

Apr.

May

ACADEMIC CALENDAR

- fall quarter classes begin — Sept. 6
- last day of classes — Nov 14
- fall / winter break — Nov 18
- winter quarter classes begin — Nov 30
- holiday break — Dec 20
- classes resume — Jan3
- last day of classes — Feb20
- winter / spring break — Feb28
- spring quarter classes begin — Mar11
- last day of classes — May18
- Commencement — May26
- Jun.3

THESIS PLAN

- Sept. 25 **3.0 Thesis Planning**
- O Sept. 25 committee final
- Nov. 13 proposal due
- Nov. 18 **4.0 Research**
- O Dec. 3
- Dec. 23 Research / Synthesis
- Jan. 10 Research / Ideation
- O Jan. 30 committee meeting
- Feb. 3 application evaluation
- Feb. 8 **5.0 Design Application**
- Mar 6 Design Implementation
- O Mar 18 committee meeting
- Apr 2 **6.0 Thesis Presentation**
- Apr 6 opening
- Apr 18
- Apr 30 **7.0 Evaluation / Documentation**
- O May10 committee meeting; evaluation
- ***thesis signing***

KEY
- O committee meetings
- (shaded) academic breaks

3.0 THESIS PLANNING

CONCERNS	Whether this thesis project has been defined as a workable problem to be solved.
QUESTIONS	1 Has a planning report been constructed, defining the major parts of the project such as: a validated problem, need, plan of attack, etc.? 2 Is the project diagram and time line a realistic plan?
PROCEDURES	1 analyze successful existing planning reports in order to rate this report. 2 submit Planning Report to Committee to have validated.
CONSTRAINTS & DIMENSIONS	1 designer's experience with thesis 2 time

4.0 THESIS RESEARCH

CONCERNS

Whether there has been enough exploration to begin the next stage of fulfilling the design implementation goal.

QUESTIONS

1 Has there been a logical progression toward working design theories that will be applied to the design application?

2 Is there sufficient amount of design ideation to begin the next stage of the project?

PROCEDURES

1 the designer will create an inventory of research instruments and resources at the beginning of 4.0. This will later act as as a checklist to evaluate how many of those resources were utilized.

2 the designer will record behavior and comments of committee members during the research process

CONSTRAINTS & DIMENSIONS

1 time
2 availability of certain books and materials

5.0 THESIS DESIGN APPLICATION

CONCERNS

Whether a design has been created that presents the theory and application of the Thesis Research.

QUESTIONS

1 Does the design solve the thesis need by providing an alternative way or ways of designing with the inclusion of different intelligences and learning styles?

2 Does the design effectively educate the user about the new view of intelligence by presenting all the intelligences?

PROCEDURES

1 presenting the design application at the Thesis show and receiving informal evaluation from the audience and committee members

2 recording the views of educators and children during interviews conducted with the design application

CONSTRAINTS & DIMENSIONS

1 educator's and children's willingness to test and evaluate the design application objectively

6.0 THESIS EXHIBIT

CONCERNS

Whether the public understood the Multiple Intelligence theory and why it is important to design with it in mind.

QUESTIONS

1 Did the presentation present the new advances in cognitive psychology, especially this theory.

2 Did it make a point to connect personally with the viewer?

3 Did it entertain and educate?

PROCEDURES

1 observe and collect behavioral information from viewers; how long do they read , look, pick things up etc.

2 compare and contrast to other, similar exhibits that have taken place in the past.

CONSTRAINTS & DIMENSIONS

1 audiences' familiarity with the theory
2 audience' willingness to concentrate on the topic
3 distractions from other exhibitors

The Thesis exhibition will be the designer's showcase of research as well as the design application. It is the culmination of Master of Fine Arts Degree Thesis with the goal of educating and inspiring designers, educators and the general audience. It will ask the audience to question the design of learning materials, and the designers role in their creation. This exhibition will be held in the Bevier Gallery at the Rochester Institute of Technology from April 2nd to the 18th, 2000, and will be evaluated by the designer, committee members advisor and audience.

Bierut, Michael, William Drenttel, Steven Heller and DK Holland. *Looking Closer 2.* NY: Allworth Press., 1997.

Booth C., Wayne. *The Craft of Research; Chicago Guides to Writing, Editing and Publishing.* NY: University of Chicago,1995.

Busic-Snyder, Cynthia, Charles Wallschlaeger. *Basic Visual Concepts and Principles, for Artists, Architects, and Designers.* NY: McGraw and Hill, 1989.

Gardner Howard. *Art Mind & Brain; A Cognitive Approach to Creativity.* NY: Basic Books Inc., 1982.

Lazear, David. *Eight Ways of Knowing; Teaching for Multiple Intelligences.* NY: SkyLight Training and Publishing Inc., 1999.

Miller K., Robert. *The Informed Argument; A multidisciplinary reader and guide.* NY: Harcourt Brace Jovanovich, Publishers, 1989.

Webster's II New Riverside Dictionary. NY: Berkley Books, 1984.

cognitive science	The scientific study of the mental processes contributing to knowing.
intelligence	The capacity to learn and to solve problems and difficulties. Mental powers.
Multiple Intelligence Theory	Howard Gardner's theory of intelligence stating that intelligence should be pluralized. Recent advances in cognitive science, developmental psychology and neuroscience suggest that each person's level of intelligence, as it has been traditionally considered, is actually made up of autonomous faculties that can work individually or in concert with other faculties. Howard Gardner originally identified seven such faculties, which he labeled as "intelligences". These include; Visual / Spatial, Verbal / Linguistic, Logical / Mathematical, Bodily / Kinesthetic, Musical / Rhythmic, Interpersonal, Intrapersonal, and a possible eighth, Naturalistic Intelligence.
visual syntax	The relation of the sign and its object in terms of "structure" of form (ie. visual organization)

Thesis Project: **Visual Communication and Intelligence**
Winter Quarter 2000 Schedule
Tanya Harding

Appendix B

Thesis Quarter Planning Calendars

Thurs., Nov. 30 classes begin
- begin thesis diary

Thurs., Dec. 7
- **present 3-4 hypothetical directions** with which to approach research and design application
- finalize an effective filing system for the collected research information
- finalize a form in which to document and evaluate interviews
- finalize 3 lists of resources to access: resource people, journals and books (used later to evaluate research phase)

Thurs., Dec. 14
- **finalize choice of subject, age range, and approach** to target with design application
- begin gathering alternative possibilities to approaching the subject in each of the different intel ligences with this age range
- begin documentation of case studies

Wed, Dec. 20 Christmas break begins
- book research & documentation, note taking (case studies, history, color theory, design of learning materials, multiple intelligence, historical design methods that may be of use)
- begin making a rough outline for known parts of Thesis Documentation

Thurs., Jan. 3 classes begin

Thurs., Jan. 4
- **present theories and conclusions / theory application**
- case study research & documentation continue

Thurs., Jan. 11
- **present rough ideation of Thesis Application** sketches begin
- book and case study research & documentation continue

Thurs., Jan. 18
- **present refined ideation of Thesis Application**
- begin production of presentation materials
- research & documentation continue

Thurs., Jan. 25
- **present plan for thesis presentation materials**
- production of presentation materials for first year graduates (case studies. . .)
- begin researching materials and pragmatic considerations for Thesis application

Thurs., Feb. 1 presentation
- beginning image collection / creation / layout
- begin production

Thurs., Feb. 8
- **present Application refinement** image collection / creation / layout

Thurs., Feb. 15
- **present Application refinement** of image collection / creation / layout

Thurs., Feb. 22
- preflight design application, gather opinions, refinement

Wed, Feb. 28

ntelligence

Spring Quarter 2000 Schedule
Tanya Harding

B.2

	Teus., Feb. 20	- last day of classes
	Mon Feb. 26	-
	Tues	
	Wed	
	Thurs	
	Fri	
	Sat	
2 weeks	Sun	
	Mon Mar. 5	-
	Tues	
	Wed	
	Thurs	
	Fri	
	Sat 10th	- dinner theatre!
	Sun	
	Mon Mar. 12	- Spring Quarter begins -GALLERY PLANNING MEETING!! 4-5:30 pm in rm. 02570 - **meeting with Roger:** plan thesis committee meeting III, go over plan for panels in show, and prototype
	Mon Mar. 19	- **meeting with Roger**:
	Mon Mar. 26	-**meeting with Roger**:
	Fri. Mar 30th	THESIS INSTALLATION MEETING 10-11am Bevier gallery (demonstrations on hanging)
	Mon Apr. 2	-**meeting with Roger**:
	Mon Apr.2	THESIS EXHIBITION BEGINS
**	Fri Apr. 6	**RECEPTION 5-7pm**
thesis show April 2 to April 19th		
	Mon Apr. 9	-**meeting with Roger**:
	Mon Apr. 16	-**meeting with Roger**:
**	Thurs Apr. 19	DEINSTALLATION OF THESIS EXHIBIT (before noon)
	Mon Apr. 23	-**meeting with Roger**:
	Mon Apr. 30	-**meeting with Roger**:
	Mon May 7	- **meeting with Roger**: plan thesis committee meeting IV (signing)
	Mon May 14	-**meeting with Roger**:
	Fri May 18	- last day of classes
	Sat May 26	- COMMENCEMENT

John Wakefield: Developing Textbooks That Teach: A Problem-solving Model Of Textbook Design

Las Vegas, June 18, 1997

John Wakefield, an educational psychologist at the University of Northern Alabama, presented a paper on textbook design at the Text and Academic Authors national convention. The full text:

Textbooks have long been considered at least partial solutions to educational problems, but they have suffered from the absence of theory. In the absence of theory, the content of textbooks is often viewed as derivative, their authors' goal is criticized as profit, and textbook authors themselves are politely characterized as "seldom the greatest thinkers of the subject" (Boorstin, 1980; Alfred and Thalen, 1993). These criticisms are similar to those which have been leveled at virtually every human endeavor prior to the emergence of a discipline. The criticisms need to be responded to not by counterclaims, but by the development of a discipline of textbook design.

From where might such a discipline come? A critical first step was a short collection of essays titled Text Materials in Modern Education (Cronbach, 1955). The focus of these essays was textbook improvement in light of a history of over-reliance upon poorly constructed materials. Progressive educators of the 1950's looked back to the laboratory education proposed by Dewey in the 1930's, and at the new principles of discovery learning then emerging, for ideas about how text materials might be improved to help students learn better.

Although a discipline of textbook design did not emerge from these essays, some specific recommendations were based on educational theory. For example, authors of text materials were advised to organize content to match the structure of a subject, so that students could learn the pattern of inquiry specific to a discipline. As a second example, authors were advised to stimulate curiosity and communicate values through narration to supplement description. Thirdly, they were advised to facilitate application of knowledge through natural problem solving. Just a few years later, a set of similar recommendations were made by Jerome Bruner (1960) for teaching at all levels of education.

What the confluence of writing with instruction suggested was a parallel between the two activities which has yet to be fully explored. Little progress was made on textbook theory over the next quarter of a century (Walker, 1980), and only comparatively recently has research on textbooks begun to accelerate (Woodward, 1988). What are textbooks that teach? How can they help solve pedagogical problems? How can their pedagogical design be improved? Such questions structure a disciplined inquiry into textbook design which can result in a model, if not a theory. I believe that this model of design has the potential to improve textbooks by helping authors to become more aware of textbook composition as a problem-solving process that parallels instruction.

What are textbooks that teach?

Developing textbooks that teach begins with understanding what they are, and what they are not. Let's begin with some historical examples. If we ask, "What are textbooks that taught?" From the time of the Roman Emperor Constantine until the Renaissance, we discover books suited to memorization. One of the most popular textbooks during this time was the Ars Minor (or Lesser Study) by Aelius Donatus, composed in the fourth century A. D. (Chase, 1929). Donatus' textbook was a Latin grammar for children, and grammar rules were presented in an innovative question-and-answer format (Appendix). Latin grammar was learned through a verbal interaction between teacher and student that resembled a catechism.

Today, we would find this form of interaction to be wooden, but in the fourth century, it represented a highly innovative strategy to achieve contemporary pedagogical goals. Donatus contributed very little to the theory of grammar, but his contribution to pedagogy was unsurpassed (Hovdhaugen, 1995). His introductory Latin textbook was widely imitated and in use for more than a thousand years -- very possibly an all-time record.

If we ask, "What are textbooks that taught?" beginning in the Renaissance, we discover a different answer -- books that emphasized knowledge derived from sensory experience. Perhaps the most innovative and effective Latin grammar of the Renaissance was the Orbis Pictus (or Picture of the World) written by John Amos Comenius (1728-1887) in the 17th century. Composed for younger or less literate children, it featured illustrations of Latin words grouped by theme and woven into sentences (Figure 1). Latin sentences were translated into the vernacular language in a parallel column, so that students could learn something of the meaning not only of Latin term, but of its translation into their own language, from looking at the picture. It too was enormously popular, remaining in print for more than 200 years.

If we ask, "What were textbooks that taught?" as recently as the mid-1980's, we discover a yet different answer: textbooks that improved reading comprehension. Instructional design, a new branch of educational psychology, found that some text features, such as questions inserted before, within or after text, helped focus reader attention and improved reading comprehension (Lindner and Richards, 1985; Friedman and Rickards, 1981). Further, research on reading comprehension (e.g., Kantor, Anderson and Armbruster, 1983) defined "considerate text" as that which was structured well enough to communicate information, coherent enough to develop understanding, unified enough to exclude irrelevant or distracting information, and appropriate to the knowledge base of the reader. Some of the features to increase reading comprehension (such as the insertion of questions) were readily adopted in textbooks, while other features remained more elusive.

If we ask "What are texts that teach?" today, we might find an answer that focuses less on reading comprehension than on higher-order activities of the learner. The cause of the shift in emphasis away from reading comprehension was the development of higher-order thinking skills as a priority of education beginning in the mid-1980's. Higher-order thinking includes intellectual skills -- such as analysis, synthesis and evaluation -- which represent more complex skills than comprehension (e.g., Bloom, 1956). In the mid-1980's, textbooks which did not facilitate higher-order thinking became the subject of widespread criticism (e.g., National Commission on Excellence in Education, 1983; Nicely, 1985). Subsequent improvements in textbooks were often related to pedagogy to develop higher-order thinking (e.g., Chandler and Brosnan, 1994; Risner, Nicholson and Webb, 1996). Text materials that teach today need to facilitate higher-order thinking to be congruent with contemporary educational goals.

This brief review suggests that "textbooks that teach" are books which evoke learner activities designed to achieve contemporary cognitive goals. This definition would include textbooks by Donatus and Comenius, because both the Ars Minor and the Orbis Pictus appear to have evoked learner activities designed to achieve cognitive goals of their time. This definition would also include any textbooks in the 1980s which evoked learner activities related to reading comprehension. Finally, this definition would include textbooks developed since the mid-1980's which evoke higher-order thinking skills of the reader.

The word that Rothkopf (1970) coined to describe learner activities in the service of educational outcomes was "mathemagenic," after the Greek roots for learning and to be born. Mathemagenic activities are not limited to activities which improve text comprehension, but in theory may be designed to achieve any specific instructional objective. Textbooks that teach do so by evoking mathemagenic activities in the context of broad cognitive goals defined by society. This definition of "textbooks that teach" would exclude instructional materials that exhibit little if any pedagogical design, such as documents of historical importance or works of fiction. These materials may be used in the context of an appropriate learning activity, but in themselves, they are not designed to achieve contemporary cognitive goals. This definition would also exclude instructional materials that are composed primarily of procedures, such as procedural manuals or activity books. Textbooks that teach may include procedures, but these procedures are ultimately subordinate to broader cognitive goals. Textbooks that teach help students attain cognitive goals through cognitive activities.

Finally, this definition of "textbooks that teach" reminds us that such works are written and adopted as solutions to educational problems situated in a given time and place. The educational problems that textbooks can help resolve are profoundly influenced by the social milieu (Bierstedt, 1955). The problems can be reduced to a word or phrase, such as "memorization," "experiential knowledge," "comprehension," or "higher-order thinking," but these terms each represent a problem framed in the context of cultural and pedagogical values, not to mention physical and intellectual resources. Failure to take into account the milieu or context for textbook design results in a textbook that could teach but will not teach, because it is not perceived as a useful means to achieve contemporary goals.

How can textbooks help solve pedagogical problems?
We all know that there is an uncertain relationship between what a textbook contains and what is taught in the classroom. By nature, this relationship seems to depend upon a number of contextual variables. Among these variables appear to be the degree of structure in the subject matter, the experience of the teacher, and the match between the goals of the textbook author(s) and those of the classroom teacher and students.

Although case studies suggest that recommendations for textbook use might be derived from correlating these contextual variables with student achievement (Ball and Feiman-Nemser, 1988; Stodolsky, 1989), no research of this type as yet exists. Existing research is limited to case study of classrooms. The most that can be said on the basis of existing research is that some textbooks appear to help some teachers achieve some pedagogical goals.

Not all educators believe that textbooks can help develop higher-order thinking in students. Some educators view textbooks as a conservative influence, inhibiting both curriculum developers and teachers in their efforts to reform curricula or redesign lesson plans to develop high-order thinking (e.g., Apple and Jungch, 1990; Ben-Peretz, 1990; Joyce and Calhoun, 1996). In their view, textbooks constrain the selection of teaching goals because they develop recall, comprehension, or application of information. These designs are perceived to foster traditional classroom activities, such as lecture, demonstration, recitation, and seatwork. The goal of these critics is to remove the constraining influence on planning by removing textbooks from the planning process. The removal of this constraint is perceived to free curriculum developers and teachers to develop goals and activities aimed at higher-order thinking.

Other educators believe that textbooks could help teachers attain the goal of developing higher-order thinking skills, if teachers were trained to use them properly (Sternberg and Martin, 1988; Young, 1990). Advocates of this position believe that training teachers to think, and to use existing textbooks thoughtfully, is prerequisite to developing higher-order thinking skills in students. They believe that textbooks which contain exercises to teach thinking are available, but either are not preferred by most teachers, or are not used to develop thinking skills.

Still other educators agree that textbooks can help teachers attain the goal of developing higher-order thinking skills, but they believe the means to achieve this goal lies in improving textbooks. These educators are continuing to call for significant changes, even after textbook revisions in the late 1980s and early 1990's (e.g., Lumpe and Beck, 1996). They accept textbooks for their potential as sources of information, but beyond the acceptance of the text as an information source, there is little agreement over further improvements.

Suggestions for designing textbooks to teach thinking appear to exist in a hierarchy, based on increasing complexity of authoring skills (Table 2). Elementary authoring skills result in the production of comprehensible text and are generally expected of text authors. Intermediate authoring skills result in the development of pedagogy, but are not always expected of text authors. (The pedagogy may be the responsibility of an instructional designer.) Complex authoring skills involve the development of authoring environments, and are not generally expected of text authors operating alone. In this section, I want to survey authoring skills to begin to explore the role of problem-solving in the design process.

Elementary authoring skills. Some reformers have argued for a minimalist approach to textbook improvement, in which textbooks would be largely stripped of pedagogy and used by students to exercise problem-solving skills taught apart from the text. The author's goal is to produce text that is accurate, current, unbiased and considerate (e.g., Ornstein, 1994; Osborn, Jones and Stein, 1985). Considerate text, as you recall, is that which is well-structured, coherent, unified and learner-appropriate. Achieving the goal of producing considerate text requires elementary authoring skills such as organizing information, developing ideas in logical relation to each other and in relation to the whole, and understanding learner characteristics. Considerate text is often regarded as fundamental to student learning, but it must be supplemented by classroom instruction to direct students toward higher-order thinking (Honebein, Duffy and Fishman, 1993; Jonassen, 1985).

A "self-conscious" variation of considerate text would add instruction in study skills beginning with the introduction of the textbook. The text would not only exhibit the virtues of considerate text, but it would begin with an explanation of the author's goals, a description of the text structure, and suggestions for a study strategy including "higher-order" questions (Anderson and Armbruster, 1985; Page, 1985). The pedagogy of the text would provide both examples of higher-order questions, and reminders to students to formulate them. In this approach, the text, as much as the teacher, would help the student set and achieve learning goals.

Intermediate authoring skills. Still other suggestions to develop student thinking call for more complex authoring skills. Some of these designs involve innovations in print pedagogy to develop the type of thinking pertinent to both the learning context and a reformed curriculum. In this approach, pedagogical innovations help the teacher achieve curriculum goals derived from contemporary content standards (Ball and Cohen, 1996). Curriculum goals include higher-order thinking skills relevant to the subject being taught. To help teach such skills, the textbook pedagogy is designed by authors and publishers to enact curicula. Enactment of curricula requires authors not only to be knowledgeable of relevant learning activities, but to adapt them for presentation in a textbook or related instructional materials. This task is complex enough that some distance educators have argued for the separate development of textbook pedagogy by an instructional designer (e.g., Carter, 1985). Whether developed by a content specialist or an instructional designer, pedagogy should include enough options for exercises and activities to respond both to the learning context and to activity preferences of the teacher.

Somewhat more complex designs use computerized pedagogy to promote higher-order thinking (e.g., Bettex, 1995; Deloughry, 1996; Whalley, 1993). The activities themselves may be little different from those ascribed to traditional textbook pedagogy or associated with ancillaries, but they are presented through an electronic medium. Electronic pedagogy ranges from that which provides only supplementary information (e.g., easy and rapid access to additional information, illustrations, or documents) to that which engages thinking more actively (e.g., involvement in problem-solving exercises or simulations). Computerized pedagogy requires skills associated with authoring hypertext or multimedia. Although relatively simple authoring tools (such as Apple's HyperCard or IBM's LinkWay) exist, their use to develop higher-order thinking in students can require sophisticated programming skills.

Complex authoring skills. Radical advocates of design reform argue for student use of authoring capabilities to develop their own textbooks (e.g., Cunningham, Duffy and Knuth, 1993). The student authors' goal is to construct comprehensible text, sometimes including material or illustrations from other sources. The result might be a personal handbook to accompany a standard textbook or a even a personalized textbook. Because the approach to authoring paper or electronic text requires students to develop authoring skills, instructional support or guidance is required (Hammond, 1993). The relationship between the teacher-author and student-author is sometimes characterized as an apprenticeship. Support or guidance may be provided through interaction with the teacher, more experienced students, or both. Such interactions in combination with authoring activities purportedly develop higher-order thinking. Skills involved in structuring authoring environments involve expertise in both teaching and the use of authoring tools.

This observation returns us to a position close to the beginning of the discussion. Researchers have not defined a unique role for textbooks in solving pedagogical problems, but proposals for what that role should be abound, ranging from suggestions that require elementary authoring skills to those that involve very complex authoring skills. These suggestions are not mutually exclusive, but represent a set of goals in a hierarchical relationship to each other. One obvious implication of this hierarchy is that elementary authoring skills are also the most fundamental -- they represent the sine qua non of developing textbooks that teach. The text must be accurate and considerate to teach, whatever the design of the classroom teacher.

The hierarchy of authoring skills also represents a sequence in the design of textbooks to teach thinking. Assuming an accurate and unbiased knowledge base, text authors can begin with the goal of producing considerate text. The development of "self consciousness" in the introduction and text can occur later. Development of pedagogy to attain the goal of higher-order thinking can occur next, and the use of electronic authoring skills -- by the teacher-author or the student author -- can occur last. Although there is no one way to develop textbooks that teach thinking, the result of following this design sequence would be a textbook "layered" to teach thinking in a rather comprehensive way.

Finally, this hierarchy of authoring skills suggests that developing textbooks that teach is still an "ill-structured" problem, or one in which relatively few of constraints, goals, or solution procedures are specified beforehand. Developing textbooks to teach higher-order thinking skills is not a process of imitating successful textbooks of the past in their content or even their form. Rather, it is a creative endeavor in which constraints, goals, and solution procedures need to be newly defined by authors and publishers during the planning and development of each textbook project.

How Can the Pedagogical Design of Textbooks Be Improved?

For a textbook to be effective, it must be written by an author who can think like a teacher. Since the 1980s, both nonfiction writing and teaching have been analyzed in terms of problem-solving processes, but these analyses have never been fully coordinated. Their coordination presents possibilities for improving the pedagogical design of textbooks, because it can help writers to think more like teachers who solve pedagogical problems.

Models of problem solving in writing (Hayes and Flower, 1980, 1983, 1986) and instruction (e.g., Popham and Baker, 1971; Dick and Carey, 1996) are similar, but not the same. Their similarity is due to three assumptions. First, they both assume that activities which they describe are goal-directed. The goal in nonfiction writing is often expressed as the writer's purpose. The goal in teaching is often expressed as an instructional goal, which is particularized in terms of student educational objectives. Second, both models assume that a problem is defined as a goal that someone wants to attain but does not immediately know how to achieve (Newell and Simon, 1972). If someone were to know how to achieve a goal, it would not represent a problem. Third, models of problem solving in writing and teaching describe similar processes.

Viewing the models side by side, rather than in the form of a flowchart, highlights the parallels between processes (Table 1). Planning the composition corresponds to setting goals, writing objectives, and developing strategies in teaching. Translating material from memory into written sentences corresponds to implementing the teaching strategies. Reviewing what has been written corresponds to evaluating the strategies in light of the objectives. These parallels suggest not only similarities between models, but compatible activities for writers who are developing instructional materials.

Problem solving in planning

In the Hayes and Flower model of composition, the task environment, which consists of the writing assignment (topic, audience, and motivating cues) and produced text, lies outside core processing activities, as does the writer's long-term memory. Among the core processes, planning consists of generating content, organizing it, and setting up writing goals and procedures. Planning begins with considering the writing assignment (topic, audience, and motivational cues such as a deadline) and retrieving relevant information from long-term memory. During planning, the writing task becomes mentally represented as a dynamic set of goals that both guide and constrain the act of writing. The goals are prioritized in a hierarchy that can change during writing as goals are reconsidered and modified. The written outcome of planning is often a sketchy outline of rhetorical goals and topic "gists."

Scholars have sometimes used of the Hayes and Flower model to develop guidance for textbook authors. Orna (1985), for example, perceive purpose for a textbook author to begin with identifying characteristics of the writing task, including the use that the audience would have for information. She suggested that during planning, textbook authors develop a structure or organization for text based on audience use. Meyer (1985) suggested that authors signal their plans to readers through text structure, even at the level of paragraph transitions. She perceived "signaling" to improve text comprehension by indicating a structure for both storage and recall.

The value of a framework or organization for text which develops out of the intended use for knowledge, and which is then signaled to the reader, cannot be overstated. Psychologists know that retrieval of information from the brain occurs most easily when the brain is in the same state it was at the time information was acquired. In other words, the writer's purpose as manifested in the organization of text must be the same as the reader's purpose in using textual information if the information is to be later recalled. Consequently, each text should be structured not only according to the discipline it represents, but according to the activities in which the reader is to engage when using information.

What can instructional design contribute to this insight? Instructional design involves a problem-solving cycle that begins with the consideration of what the problem is. Problems are broadly defined by the differences between what should be and what is (Rossett, 1987). The "shoulds" can be gathered from a number of sources including consideration of broad cultural norms and existing instructional materials as well as market surveys and curriculum objectives. The differences between "what is" and "what ought to be" generally represent needs for instruction, which may be cognitive, affective, or psychomotor. The needs for instruction are then transformed into goals and objectives by considering constraints on learning, such as characteristics of the learner, available technologies, and other resources. One outcome of planning is a set of goals for instruction that can be particularized as student educational objectives.

These objectives, each of which begins with a verb that describes a student action, often identify learning activities (such as "develop a positive attitude toward learning to write," or "plan an experiment to develop a scale of hardness for a given set of materials"). Student educational objectives particularize learning activities that can structure text. Developing a positive attitude toward writing, for example, requires not only information about writing as a learnable skill, but willingness to learn that can be developed through reading a persuasive introduction. Planning an experiment to develop a hardness scale requires not only understanding what an experiment is, but a model experiment, and enough scaffolding in instructions to support the efforts of a student to plan his or her own experiment. The outcome of textbook composition becomes usable text, not just informative text.

The match between the structure of a text and learning activities is crucial when the goals for learning involve higher-order thinking. It is not sufficient to say that text should be considerate, that is, well-structured, coherent, unified, and learner appropriate. An author needs to particularize what these qualities mean if text is to help achieve the goal of developing higher-order thinking.

To be considerate of thinking, text must be responsive to higher-order thinking both in the discipline and in the reader. A text that is well-structured for thinking is not simply hierarchically arranged; rather, its organization must reflect the core processes of a discipline, such as the writing process in composition, or the processes of inquiry in a particular science. A text that is coherent in thinking is not simply logical; rather, its logic must reflect patterns of thinking in the discipline, such as cause / effect in history, or problem / solution in a science (Armbruster and Anderson, 1985). A text that is unified by thinking is not simply united by a theme; rather, it presents and re-presents the questions that structure a given discipline. Finally, a text that is appropriate to the thinking of the learner does not simply have an appropriate reading level; rather, it engages the learner in higher-order thinking that is appropriate to the learner's cognitive abilities.

Similarly, an author needs to particularize what is meant by "self-conscious" text if a text is to develop higher-order thinking skills. This particularization is made easier by teaching goals which specify what the higher-order thinking skills are. A self-conscious text, for example, will differ from a considerate text in making the reader aware of how the text structure reflects the core processes of the discipline; how the text demonstrates patterns of thinking relevant to a discipline; how it presents and re-presents key questions; and both names the higher-order thinking processes it engages, and explains how it engages them. Further, instructional objectives make design of pedagogy easier, whether the pedagogy is developed in paper or electronic form. Objectives for learning a subject should suggest the type of learning activities that lead to the development of higher-order thinking in that subject. Some of these learning activities -- such as individual or group inquiries, debates, simulations, and projects -- can be embedded in the pedagogy.

Instructional objectives can even guide the construction of text by students. As mentioned above, constructing considerate text requires an understanding of not only the reader, but an understanding of core processes, patterns of thinking, and recurrent questions of a given discipline. Consideration of these elements of a discipline and consideration of their readers' knowledge and thinking in the course of constructing paper or electronic text can lead students to discover much about the discipline at their own (as well as others') level of understanding. Such discoveries are time consuming, but they result in the construction of an understanding which permits students to make sense of their world.

Problem solving in translating

In the Hayes and Flower model, translation involves the expression of ideas into sentences and occurs under the guidance of the writing plan. Ideas are probably not stored in long-term memory as language but as propositions (e.g., relating concept to concept, or concept to attribute), so translation explains how propositions are transformed moment by moment into language. Research by Kaufer, Hayes and Flower (1986) demonstrated that this type of translation is not a routine skill, but is effortful and goal-directed. It represents a problem-solving at the moment of writing sentences.

What can problem solving by instructional designers contribute to this observation? The answer is that instructional designers have made some progress toward the discovery of how authors develop comprehensible text (Duffy et al., 1989). This research used "think alouds" by writers, as well as interviews, to discover the moment by moment goals and strategies experts use when they rewrite text.

What researchers found is that categorical goals of experts such as "improve structure," "develop coherence" or "increase interest" do not necessarily improve the comprehensibility of text. One experiment (Graves et al., 1988), which pitted Time-Life editors against composition teachers and text linguists in efforts to rewrite a 400-word passage from a high school history textbook, found that rewrites by Time-Life editors were twice as effective in increasing student recall as rewrites by the teachers and linguists. The changes by Time-Life editors focused on increasing interest (making passages more dramatic and personal), whereas those by composition teachers and text linguists focused on improving structure or developing coherence. This study pointed to a motivational goal (increasing interest) as the source of improving comprehension, but attempts to replicate the results failed (Britton et al., 1989; Duffy et al., 1989). What both replication efforts found was that texts rewritten by composition teachers improve comprehensibility more, but improved composition was the result of simplifying sentence structure, not altering the structure of information.

These results suggest that what an author does to produce comprehensible text may not be replicable from author to author or even text to text. This situation makes the development of guidelines for producing comprehensible text nearly impossible. Duffy and colleagues (1989) concluded that producing comprehensible text is an ill-defined problem which requires cognitive flexibility to solve. Cognitive flexibility is developed not through following guidelines to generate text, but through studying a series of "multidimensional examples that reflect the inter connectedness of the features" (Duffy et al., 1989, Page 453) that enhance comprehension. What should develop is not a set of personal guidelines for writing, but a skill of thoughtfully implementing a writing plan, so that what is written is responsive to the needs of learners moment by moment.

The distinction between this problem-solving skill and planning skills is described in the literature on teaching as the distinction between reflection in action and reflection on action (Schon, 1983). Reflection in action involves spontaneously solving teaching problems as they arise. Some of these classroom problems arise because of unexpected behavior, some because of misunderstanding information. Reflection in action requires sensitivity to moment-by-moment problems in communicating expectations and information. This skill of "thinking on your feet" probably reaches its zenith in first few years of teaching, however, and wanes as expertise develops in handling routine situations (Wakefield, 1996).

Translation of ideas into comprehensible sentences may require a similar skill of "thinking on your seat" during composition -- guiding the comprehension of the reader through information of uneven difficulty. "Thinking on your seat" requires a sensitivity to the audience, and understanding which information needs simplification, which needs illustration, which elaboration, and so on, to develop student comprehension of text. Reflection in action to develop higher-order thinking skills is more problematic. Teachers who become reflective practitioners routinely inquire about causes and effects in the course of their teaching (LaBoskey, 1994). They possess curiosity. It may be that rhetorical strategies such as interrogation of the reader, rhetorical questioning, thought experiments, and expressions of wonder can model curiosity on the sentence level. It would not be surprising if an "inquiring mind" were to be manifested in an author's style as he or she writes, but it is doubtful that guidelines can be created which develop this expressive component of writing.

Problem solving in reviewing

Reviewing involves evaluating what has been planned or written. In the original Hayes and Flower (1980) model, reviewing consisted of reading and editing, but in later versions of the model (e.g., Hayes and Flower, 1983, 1986), it consisted of evaluating and editing. This change appears to have developed from the perception that only when the outcome of evaluation was negative did authors engage in editing.

Reviewing the literature on revision skills, Hayes and Flower (1986) noted that the more expert the writer, the more time was spent in revision as opposed to planning or translating. Expert writers were more attentive to global problems, and were more likely to change the meaning of what they had written, than were novice writers. Expert writers were more likely than novices to set goals for revision in light of a large portion of text, and less likely than novices to focus on individual words and phrases.

Their literature review suggests that reviewing is a problem-solving activity relatively independent of planning or translating. What triggers goal setting in evaluation is the detection of faults through either a sense of incongruity between the writer's purpose and the text produced so far, or a negative evaluation of the writing plan, or even a failure to comprehend what has been written. Detecting minor faults results in a revision strategy, whereas detection of major faults results in a rewrite strategy.

Detecting faults is easier in evaluating others' writing than in evaluating one's own, so strategies for evaluating and editing frequently involve people other than the writer. The purpose of the involvement of others is not to transfer responsibility for evaluation to others, but to increase the accuracy of the evaluation, and often to help set goals for revision or rewriting. Accuracy of evaluation generally involves two technical subgoals known as reliability and validity. In general, an adequate number of others involved in evaluation helps attain the subgoal of reliability, and careful selection of an evaluation procedure to assess the achievement of text goals helps attain the subgoal of validity.

Ironically, the research on revision by people other than the author suggests that often, while people other than the author should be involved in evaluation, the author should do the revising. In some instances, revisions by experts other than the original author have increased the comprehensibility of an original document, but in other cases, they have not (Hayes and Flower, 1986; Wright, 1985). For this reason, the original text author is frequently responsible for revising his or her own text using feedback from others including both experts of various types and students. Expert appraisals are generally most useful for content revisions, while student tryouts are useful for increasing learnability, or the ease with which students can learn from text (Britton et al., 1991; Nathenson and Henderson, 1980).

Instructional designers have contributed greatly to our understanding of how student feedback should be involved in reviewing instructional materials, including textbooks. Some of the most useful contributions have been from Nathenson and Henderson (1980), who helped develop courses for the Open University in Great Britain. Their insights were based on action research in the 1970s to evaluate and revise distance education materials prior to publication. Formative evaluation by learners could provide feedback to developers during materials development, while summative evaluation could only provide information about the characteristics of the final product to users.

Nathenson and Henderson discovered that formative evaluations using student feedback need to be planned carefully. Because of students' need for accurate content, expert appraisals of material should occur before student tryout; because of production schedules, timing of student feedback was of the essence; and because of the need to maximize the quality of student feedback, tryouts with individuals or small groups should occur before field testing. The use of a small group of students (20 to 40) for tryout was optimal because it provided qualitative feedback in sufficient quantity make reliable inferences about the material. The use of a small group similar to the ultimate users of the material allowed inferences to be valid.

With regard to data collection, Nathenson and Henderson found that performance data and process information were both desirable. On the one hand, performance-related data could be used to determine whether instructional intents had been realized. It could be obtained from test scores or performance assessments. On the other hand, process data could be used to determine how students learned from the text. Process data could be obtained from student feedback questionnaires. Student feedback questionnaires inserted in the text were especially useful because students responded to them immediately after learning from text, and they sometimes suggested strategies for improvements.

Process data were routinely collected with respect to clarity, level, action and time. Clarity involved questioning whether the presentation of the material (e.g., language, style, diagrams) was clear. Level involved asking whether students had sufficient previous experience with the material to understand it. Action involved asking learners about what they had done in response to the features or exercises. Assessing attitude involved questioning them about how they felt in response to materials or exercises. Time involved asking how long they spent studying, the single most important indication of how much they learned. In revising materials, authors either added, deleted, moved or modified material in response to student feedback.

Of particular importance in developing higher-order thinking is the category of action: what learners do in response to materials. Evaluating what they do begins with finding out what actions they take in response to features designed to develop higher-order thinking, either through performance samples, their response to feedback questions, or both. For example, authors need to know whether students use thinking skills exercises, and if they do use them, how they use them. Developers of texts that purport to teach thinking need to know whether or not the text is actually teaching thinking, and if not, how it can be revised to attain this goal.

Perhaps more than most other instructional designers, Nathenson and Henderson perceived formative evaluation to operate as a problem-solving process within a larger design cycle. This perception is consistent with a model of composition in which reviewing is both a goal-directed process and at the same time a component of a larger process of composition. The goal of reviewing is first an accurate evaluation in light of the goals for writing, and then revision or editing to improve the text as a tool to achieve these goals. In terms of higher-order thinking, the goals of reviewing are:

· An accurate evaluation of whether or not the text teaches higher-order thinking.
· A revision of the text as a tool to do so

Because this process is cyclical, it has no end until the text achieves its goal.

Conclusion

What I have found to be striking about all the problems solved by a writer is that researchers generally perceive them to be ill-structured. Authors and publishers are left to their own resources to define constraints, set goals, and determine solution procedures. There is no "formula" for success, and those that are devised, from specific guidelines for authors to readability formulas, are repeatedly found by researchers to be unnecessarily constraining. Their application does not develop a text that teaches.

My argument has been that what can help develop a textbook that teaches is a general model and a set of principles, not a set of specific guidelines. This model defines what a text that teaches is, permits analysis of the different ways a text can teach, and suggests principles for textbook development -- all in a general rather than a specific way. A problem-solving model of textbook design accomplishes these ends without being unnecessarily constrained by the circumstances of a particular milieu, let alone a particular case.

As an extended illustration of the usefulness of a problem-solving model of design, I have applied it to the problem of developing higher-order thinking skills. The development of higher-order thinking represents a central goal of contemporary education, but a problem-solving approach could be just as well applied to developing knowledge or even rote memorization. A problem-solving approach to text design does not require a goal of higher-order thinking, but it does require a goal.

That perhaps is its weakness. A problem-solving model does not easily account for "illogical" contributions to textbook development through imitation, trial and error, serendipity, or empathy, yet all of these exist in the real world of writing and publishing. Nor does this problem-solving model address the economic problem of producing text profitably, or the personal problem of developing a product as part of a team (Schramm, 1955). The problem-solving model of textbook design developed here can only suggest that a knowledge base is growing for a discipline of textbook design.

Table 1:
Problem-Solving in Writing and Instruction

WRITING PROCESSES	INSTRUCTIONAL PROCESSES
Planning	Goal setting
Gathering information	Identifying goals
Organizing content	Writing objectives
Developing a strategy	Sequencing content
Implementing the strategy	Translating
Evaluating the strategy	Reviewing
Editing	Evaluating

Table 2:
A Hierarchy of Authoring Skills*Complex authoring skills:*
Apprenticing student authors

Intermediate authoring skills:
Computerizing pedagogy
Innovating print pedagogy

Elementary authoring skills:
Developing self-conscious text
Developing considerate text

The Theoretical Basis for MI Theory

Many People look at the eight categories – particularly musical, spatial, and bodily kinesthetic – and wonder why Howard Gardner insists on calling them intelligences, and not talents or aptitudes. Gardner realized that people are used to hearing expressions like "He's not very intelligent, but he has a wonderful aptitude for music"; thus, he was quite conscious of his use of the work intelligence to describe each category. He said in an interview, "I'm deliberately being somewhat provocative. If I'd said that there's seven kinds of competencies, people would yawn and say 'Yeah, yeah.' But by calling them 'intelligences' I'm saying that we've tended to put on a pedestal one variety called intelligence, and there's actually a plurality of them, and some are things we've never thought about as being 'intelligences' at all". To provide a sound theoretical foundation for his claims, Gardner set up certain basic "tests" that each intelligence had to meet to be considered a full-fledged intelligence and not simply a talent, skill, or aptitude. The criteria he used include the following eight factors.

Potential Isolation by Brain Damage.
Through his work at the Boston Veterans Administration, Gardner worked with individuals who had suffered accidents or illnesses that affected specific areas of the brain. In several cases, brain lesions seemed to have selectively impaired one intelligence while leaving all the other intelligences intact. For example, a person with a lesion in Broca's area (left frontal lobe) might have a substantial portion of his linguistic intelligence damaged, and thus experience great difficulty speaking, reading, and writing. Yet he might still be able to sing, do math, dance, reflect on feelings, and relate to others. Aperson with a lesion in the temporal lobe of the right hemisphere might have her musical capacities selectively impaired, while frontal lobe lesions might primarily affect the personal intelligences.

Gardner, then, is arguing for the existence of eight relatively autonomous brain systems – a more sophisticated and updated version of the "right-brain / left-brain" model of learning that was popular in the 1970's.

The Existence of Savants, Prodigies, and Other Exceptional Individuals.
Gadner suggests that in some people we can see single intelligences operating at high levels, much like huge mountains rising up against the backdrops of a flat horizon. Savants are individuals who demonstrate superior abilities in part of one intelligence while their other intelligences function at a low level. They seem to exist for each of the eight intelligences. For instance, in the movie Rain Man (which is based on a true story), Dustin Hoffman plays the role of Raymond, a logical mathematican savant. Raymond rapidly calculates multi digit numbers in his head and does other amazing mathematical feats, yet he has poor peer relationships, low language functioning, and a lack of insight into his own life. There are also savants who draw exceptionally well, savants who have amazing musical memories (e.g.. playing a composition after hearing it only one time), savants who read complex material yet don't comprehend what they're reading (hyperlexics), and savants who have exceptional sensitivity to nature or animals.

Excerpt from *Multiple Intelligences in the Classroom* by Thomas Armstrong

Appendix E
The Relationship of MI Theory to Other Intelligence Theories

The relationship of MI Theory to other Intelligence Theories

Gardner's theory of multiple intelligences is certainly not the first model to grapple with the notion of intelligence. There have been theories of intelligence since ancient times, when the mind was considered to reside somewhere in the heart, theories of intelligence have emerged touring anywhere from 1 (Spearman's "g") to 150 (Guilford's Structure of the Intellect) types of intelligence.

A growing number of leaning style theories also deserve to be mentioned here. Gardner has sought to differentiate the theory of multiple intelligences from the concept of "learning style".

He writes, "The concept of style designates a general approach that an individual can apply equally to every conceivable content. In contrast, and intelligence is a capacity, with it's component processes, that is geared to a specific content in the world (such as musical sounds or spatial patterns) (Gardner, 1995, p. 202-203)".

There is no clear evidence yet, according to Gardner, that aperson highly developed in spatial intelligence, for example, will show that capacity in every aspect of her life (e.g.., wash the car spatially, reflect on ideas spatially, socialize spatially). He suggests that this task remains to be empirically investigated (for example of an attempt in this direction, see Silver, Strong, and Perini, 1997)

At the same time, it is a tempting project to want to relate MI theory to any of a number of learning style theories that have gained prominence in the past two decades, because learners expand their knowledge base by linking new information (in this case, MI theory) to existing schemes or models (the learning style model they're most familiar with). This task is not so easy an undertaking, however, parly because of what we've suggested above, and partly because structure than many of the most current leaning-style theories. MI theory is a cognitive model that seeks to describe how individuals use their intelligences to solve problems and fashion products. Unlike other models that are primarily process oriented, Gardner's approach is particularly geared to how the human mind operates on the contents of the world (objects, persons, certain types of sounds). A seemingly related theory, the Visual-Auditory-Kinesthetic Model, is actually very different from MI theory, in that it is a sensory-channel model (MI theory is not specifically tied to the senses (it is possible to be blind and have spatial intelligence or to be deaf and be quite musical). Another popular theory the Myer-Briggs model, is actually a personality theory based on Carl Jung's theoretical formulation of different types of personalities. To attempt to correlate MI theory with models like these is akin to comparing apples with oranges. Although we can identify relationships and connections, our efforts may resemble those of the Blind Men and the Elephant: each model touching on a different aspect of the whole learner.

Excerpt from *Multiple Intelligences in the Classroom* by Thomas Armstrong

THE UNIVERSITY OF THE STATE OF NEW YORK

MathematicsResource Guide
with
Core Curriculum
http://www.nysed.gov

PREFACE

The Mathematics Resource Guide with Core Curriculum is one of four documents recently developed by the New York State Education Department. These documents were designed to provide guidance to districts and schools in New York State for development of local curricula, instruction, and assessment that meets local needs and resources and aids their stu-dents in achieving the mathematics standards for New York State. The first document of the series, The Learning Standards for Mathematics, Science, and Technology(1996), introduced standards and benchmark performances in mathematics, science, and technology for grades four, eight, and high school. The Mathematics, Science, and Technology Resource Guide (1997), which is periodically updated, extended the standards into classroom practice. The Resource Guidecontains lesson plans for mathematics, science, or technology classes as well as lessons that integrate them. The Mathematics Test Samplers for grades 4 and 8 were distributed in February 1998 and for Math A in May 1998. They provide a variety of assessment items similar to those which will be used in the New York State Testing Pro g r a m .The Mathematics Resource Guide with Core Curriculum elaborates upon the standards document and provides connections among the other three documents mentioned above. The Core Curriculum is not intended to be the mathematics curriculum for school districts but instead an outline of curriculum to be used to aid districts in developing local curriculum that is reasonable for their local resources and needs. Although the Core Curriculum addresses only Standard 3 of the Learning Standards for Mathematics, Science, and Technology, a comprehensive mathematics curriculum would also include Standard 1 (inquiry, mathematical analysis, design), Standard 2 (information systems), Standard 6 (interconnectedness), and Standard 7 (interdisciplinary problem solving). The curriculum would also have connections with English language arts through the use of children's literature, reading, and writing as well as with social studies, which provides many opportunities to examine and analyze data.The C o re Curriculum extends the key ideas and performance indicators of Standard 3 to additional grade-level blocks of prekindergarten to kindergarten, grades 1 to 2, grades 3 to 4, grades 4 to 5, grades 7 to 8, and Math A. A draft of Math B is also included. Suggestions for grade-level content are given for each performance indicator. Suggestions of relevant assessment items or classroom activities are provided for each performance indicator. More examples of assessment items can be found in the Test Samplers and pilot tests. More examples of classroom activities can be found in the Mathematics, Science, and Technology Resource Guide. None of the documents just described are meant to stand alone. They should be used together. The Core Curriculum is divided into three sections: Overview, Core Curriculum (Elementary, Intermediate, High School), and Reference List. The Overview presents a discussion on processes that students use and the roles of manipulatives, technology, and assessment. Suggestions of effective instructional strategies will be discussed and each key idea of the standards will be listed and explained.The Core Curriculum section is divided into three parts: Elementary, Intermediate, and High School. In the beginning of each part are suggestions for manipulatives. This is followed by suggestions of content for each performance indicator. Examples of assessment items are included for grade levels in which there will be State assessments. There will be suggestions for classroom activities or problems for each performance indicator for which an appropriate assessment item is not available. The assessment items and classroom activities are found at the end of each grade-level block and are listed by performance indicator (e.g., 1A. would be the first performance indicator given for Key Idea 1, which is mathematical reasoning).

The Reference List at the end of this document includes all sources used for examples of assessment items, classroom activities, and problems. Teachers may wish to refer to them for more ideas.

F.3

CONTENTS

Mathematics
Core Curriculum

I. OVERVIEW

Standard 3: Mathematics

Students will understand mathematics and become mathematically confident by communicating adreasoning mathematically, by applying mathematics in real-world settings, and by solving problems through the integrated study of number systems,geometry, algebra, data analysis, probability, and trigonometry.

Key Ideas

Mathematics curriculum and assessment of mathematical proficiency based on the mathematics standard of the Learning Standards for Mathematics, Science, and Technology revolve around the seven key ideas. The mathematics standard describes the seven key ideas listed below. Classification of mathematical content into these key ideas inevitably involves some overlap. In addition, many key ideas involve students in synthesizing knowledge across mathematical topics. A mathematics program that includes New York State's standards and reflects the revised assessments will continue to emphasize the fun-damental mathematical skills and knowledge that have been traditionally expected. Students are still expected to master basic skills of arithmetic, geometry, algebra, trigonometry, probability, and statistics. The State Education Department will continue to assess these skills and concepts with tests that will be given in secure settings, and the results of these tests will be made public each year. The seven key ideas of the learning standards are a mixture of content and process goals. They speak to the mathematics content that a student should know and, at the same time, describe the ways in which the student ought to be able to use that content in meaningful contexts. This is possible by considering the key ideas as guides for selecting appropriate con-tent. The following brief description of each key idea may help in that selection.

1. Mathematical Reasoning

Students use mathematical reasoning to analyze mathematical situations, make conjectures, gather evidence, and construct an argument. Mathematical analysis is an integral part of problem solving. As a result, this key idea cuts across the content in all the other key ideas. At the elementary level, it includes the concept of pattern and at the high school level includes the concepts of logical terms such as and, or, not, if. . .then, as well as to what constitutes a valid argument.

2. Number and Numeration

Students use number sense and numeration to develop an understanding of the multiple uses of numbers in the real world, the use of numbers to communicate mathematically, and the use of numbers in the development of mathematical ideas. Although number and numeration deal heavily with number concepts of whole numbers, fractions, decimal fractions, ratios, percents, integers, and irrational numbers, this key idea also includes procedures for ordering numbers and apply-in them to real-world situations.

3. Operations
Students use mathematical operations and relationships among them to understand mathema ics.Often considered to be primarily procedural, operations includes the expectation that students understand the concepts of addition, subtraction, multiplication, and division in order to be successful with problem solving. Problem solving often requires the selection of appropriate computational or operational methods. The concepts of ratio and proportion must beunderstood in order to recognize and solve problems that are proportional in nature.

4. Modeling/Multiple Representation
Students use mathematical modeling/multiple representation to provide a means of presenting, interpreting, communicating, and connecting mathematical information, and relationships. Most geometry concepts are included in modeling/multiple representation but the key idea also includes procedures for geometric constructions and producing graphs and tables. Modeling/multiple representation deals with many aspects of mathematical communication. As a result, it includes the use of variables, modeling relationships both algebraically and graphically, and appropriate use of functions.

5. Measurement
Students use measurement in both metric and English measure to provide a major link between the abstractions of mathemat -ics and the real world in order to describe and compare objects and data. Measuring is a procedure that includes the concepts of area, volume, perimeter, and circumference. It also includes the for-mulas that may be applied to calculate them. Much of the content of trigonometry and statistics is included in this key idea. Measurement is a major mathematics key idea that connects with science, technology, and social studies.

6. Uncertainty
Students use ideas of uncertainty to illustrate that mathematics involves more than exactness when dealing with everyday sit -uations. Estimation and probability are the major topics found in the key idea of uncertainty. Most probability concepts are found in this key idea as well as procedures for calculating probabilities. Although estimation includes number sense, estimat-ing can be used as a problem-solving strategy. This key idea includes estimation of quantity, estimation of computations, and estimation of measurements.

7. Patterns/Functions
Students use patterns and functions to develop mathematical power, appreciate the true beauty of mathematics, and construct generalizations that describe patterns simply and efficiently. The study of patterns and functions is one of the central themes of mathematics. Patterns are a major part of mathematics study in the elementary grades. Astudy of patterns requires the conceptual understanding of recognizing, describing, and generalizing patterns. The study of function helps the student to build mathematical models that can be used to predict the behavior of real-world phenomena that have observable patterns. The widespread occurrence of regular and chaotic pattern behavior can make a study of patterns and functions interesting and valuable. Patterning and the manipulation of functions (algebraically and graphically) have procedural aspects, but pattern seeking and function finding are strategies used in problem solving. As in the key idea of mathematical reasoning, which includes looking for patterns, key idea 7 cuts across the other key ideas.

Meaningful curriculum and assessment take into consideration the three categories of cognitive functioning that have served in shaping the National Assessment of Educational Progress (NAEP) and many other state frameworks and large-scale assessments of student learning in mathematics. These categories are procedural knowledge, conceptual under -standing, and problem solving. Procedural knowledge involves "knowing when and how." Conceptual understanding involves "knowing about." They are joined together by problem solving, which involves the merging of conceptual under-standing with procedural knowledge to bring students' knowledge into use in solving problems in abstract or contextual settings.

1 Students use procedural knowledge when they:

- select and apply appropriate procedures correctly;
- verify or justify the correctness of a procedure, using concrete models or symbolic methods;
- extend or modify the procedures to deal with factors inherent in problem settings;
- use various numerical algorithms;
- read and interpret graphs and tables;
- execute geometric constructions; and
- perform non-computational skills such as rounding and ordering numbers.

2 Students use conceptual understanding of mathematics when they:

- recognize, label, and generate examples with a concept and without a concept;
- use and interrelate models, diagrams, manipulatives, and varied representations of concepts;
- identify and apply principles (i.e., valid statements generalizing relationships among concepts in conditional form);
- know and apply facts and definitions;
- compare, contrast, and integrate related concepts;
- recognize, interpret, and apply the signs, symbols, and terms used to represent concepts;
- interpret the assumptions and relations involving concepts in mathematical settings; and
- reason in settings involving the careful application of concept definitions, relations, or representations of definitions or relations.

3 In problem solving students are required to use their accumulated knowledge of mathematics in new situations when they:

- recognize and formulate problems;
- determine the sufficiency and consistency of data;
- use strategies, data, models, and relevant mathematics;
- generate, extend, and modify procedures;
- use reasoning (i.e., spatial, inductive, deductive, statistical, or proportional) in new settings; and
- judge the reasonableness and correctness of solutions.

Problem solving is the connecting thread through the seven key ideas of mathematics and the grade levels. Content which may require procedural knowledge for an older student may be a problem-solving task for a younger student. For example, a fourth grader can easily multiply two numbers by using a taught algorithm, but a first grader who may be unfamiliar with multiplication would have to devise a strategy to find the product, perhaps by making equal-sized groups of counters .

The Role of Assessment

Assessment is an ongoing process and not an end in itself. Acombination of individual student work, student projects, and teacher observations can be used to assess student achievement.School districts may use assessment data to adjust curriculum and instruction. Teachers may use assessment data to strengthen the teaching and learning process in the classroom, monitor students' work and progress, and identify students' strengths and areas in need of improvement. Students may evaluate their own learning by using assessment data. Parentsmay be partners in assessment and receive specific information about their child's progress.

New York State Testing Program

The seven key ideas mentioned previously are one of three dimensions that are considered in the construction of State assessments. The three categories of cognitive functioning are another dimension. The third dimension of the model for specifying the nature of State mathematics assessments is the type of questions and tasks that students would be expect-ed to complete when illustrating their competence in the key ideas and categories of cognitive functioning. These formats include multiple choice questions, short constructed response problems, and extended constructed response problems. Multiple choice questions provide a highly reliable and efficient way of assessing students' ability to select correct answers and interpretations from a listing of possible alternatives. Short constructed response problems provide much of the same information, but the student must develop the response. The student is also expected to create the answer, or sketch a drawing, among other possible actions. Such problems can be scored with a rubric that allows for partial credit. Extended constructed response problems require students to develop a written description of the solution to a problem or to answer a series of subquestions. This requires the student to demonstrate greater knowledge and a necessity to com-municate,in some depth, about the problem and its solution. Such tasks are usually scored with the use of a scoring rubric that also allows for partial credit. Examples of each type of question can be found in the Core Curriculum section at the grade levels for which State pilot assessments have been administered (grades 4, 8, and Math A). There will be a mixture of question types on all the mathemat-icsassessments. Specified percentages of items will assess each of the seven key ideas and three categories of cognitive functions.

Effective Instructional Strategies

Students develop their own meanings of mathematical concepts and procedures when given the opportunity to become actively involved in learning. Teachers who use instructional strategies guided by this principle act as facilitators for children's active development of mathematics. They do not act merely as dispensers of rules and algorithms for students to memorize. Some of the instructional strategies they incorporate are the use of manipulative materials, student discussion of mathematical ideas, and small group learning. Active involvement on the part of the learner has the potential to deepenunderstanding of mathematics.

Adapted from Association of Supervision and Curriculum Development Curriculum Handbook. (1995). Alexandria, VA: Association of Supervision and Curriculum Development, pp. 4.55-4.101.

Research concerning cooperative learning has indicated that students in classes using this learning model do at least as well and often better on standardized tests. Students from minority and low-income groups are frequently those who show the most improved scores. Other advantages of cooperative learning that have been found include development of thinking skills, improved self-esteem, improvement of attitudes toward minorities, and acceptance of mainstreamed stu-dents. Cooperative learning models have been shown to work well in heterogeneous classes. It must be pointed out that all "small group work" is not cooperative learning. The key elements of the cooperative learning model are that each studentin the group is accountable for the final result and the students in the group must work together as a team in order to succeed.

Instruction that employs a wide range of representations and contextual environments enhance student growth in both affective and cognitive dimensions. The study of mathematics focuses on the representation and communication of numerical, spatial, and data-related relationships. Many classroom activities can support that focus; for example, students may translate their mental conceptions into symbolic forms and then provide a verbal description of the same situation. Other activities might include selecting the best model to physically explain a relationship; using technology in innovative ways to explore a problem; and writing paragraphs, letters, or journals to explain observations about mathematics. Developmentally appropriate instruction takes advantage of what students are ready to learn. It provides classroom dis-course that stimulates cognitive growth. It does not require students to memorize material that is beyond their current understanding. To make use of the notion of developmental stages, teachers observe their students closely and provide them with activities for which they are ready. Hands-on activities, as well as paired, group, and class discussions in whichstudents develop and debate their ideas, contribute to the development of cognitive growth. Mathematics environments that are embedded in real-world situations engage students in authentic problems that require creativity and demonstrate its uses in everyday life and careers, as well as play. When school mathematics builds on the mathematics that children developed on their own before they came to school, it becomes practical and relevant.

Role of Manipulatives

Manipulatives are physical objects that students can move around, group, sort, and use to measure as they model mathe-matical concepts and problems. Manipulative-rich environments may enhance understanding and achievement across a variety of mathematics topics if they are explicitly connected with the mathematical concepts and procedures they represent. Students do not automatically make connections between concrete representations of concepts or procedures and their written or symbolic forms. It is necessary for the teacher to help students make the connection. Teachers of the early grades commonly use manipulatives but even when studying calculus, students can benefit from manipulating a physical model. Manipulatives can be elaborate and expensive, teacher-made, or simple items from home. Commercial materials often include books, games, and lessons when purchased in classroom sets. Suggestions for com-monly used manipulatives will be given at the beginning of each level in the Core Curriculum section.

Prekindergarten to Kindergarten
Grades 1 to 2
Grades 3 to 4

Some Manipulatives
Simple counters Pan balance scales Blocks of different sizes
Clocks Thermometers Pattern blocks
Tangrams Square tiles* Fraction models
Base 10 blocks Connecting cubes Geoboards
Dice Spinners 3-dimensional solids
Sandbox Water table Meter sticks
Rulers* Tape measures Pattern blocks*
Measuring cups and spoons Pentominoes
*Punch-outs of these are used on the grade 4 State assessment.
Calculator Four-function (optional parenthesis keys). Not permitted on grade 4 assessment.
Note; The elementary level of the Core Curriculum that follows is separated into grade-level blocks of prekindergarten to kindergarten, grades 1 to 2, and grades 3 to 4.

Students in grade 4 are expected to demonstrate proficiency with all the elementary performance indicators as given in
Standard 3 of the Learning Standards for Mathematics, Science, and Technology. The grade 4 State assessment may test any of the topics listed in the Core Curriculum with each performance indicator. The examples of assessment items for grades 3 to 4 were taken from the 1998 Test Sampler. Suggestions for classroom activities are substituted for any performance indicator which was not represented in the Test Sampler. Assessment items are not provided for prekindergarten to kindergarten or grades 1 to 2 because there are no State assess-ments at those levels. Suggestions for possible classroom activities or problems are given to provide clarification of each performance indicator. Key ideas and performance indicators have been adapted and in some cases eliminated for grade-level blocks prekinder-garten to kindergarten and 1 to 2 to provide an example of how district curriculum might provide a scope and sequence for the elementary level of their curriculum. Topics in these cases are labeled MAY INCLUDE,which is meant to indicate that school districts may arrange curricula in other ways to fit their own needs and resources.

Note that these additions to the NYState Curriculum standards have been added in the last 2 years. NYstate Curriculum is the most advanced in the United States

Key Idea 1

Mathematical Reasoning

Students use mathematical reasoning to analyze mathematical situations, make conjectures, gather evidence, and construct an argument.

Grades:3-4

PERFORMANCE INDICATORS

1A. Use models, facts, and relationships to draw conclusions about mathematics and explain their thinking.

1B. Use patterns and relationships to analyze mathematical situations.

1C. Justify their answers and solution processes.

1D. Use logical reasoning to reach simple conclusions.

INCLUDES

- Study factor and product relation-ships, using number lines and arrays.
- Statements that use and, or, and not.
- Draw pictures, diagrams, and charts to represent problems.
- Clarify problems, using discus-sions with peers.
- Addition, subtraction, multiplica-tion in number patterns.
- Patterns in sequences of numbers such as triangular and square numbers.
- Symmetry or patterning in number tables.
- Money as related to fractions and decimals.
- Verify an answer to a problem.
- Use estimation, number relation-ships, and mathematical checks to justify answers.
- Use concrete objects, diagrams, charts, tables, and number lines to help solve problems.
- Use open sentences, patterns, rela-tionships, and estimation as strate-gies to solve problems.
- Identify missing information in a story problem.

Number and Numeration

Students use number sense and numeration to develop an understanding of the multiple uses of numbers in the real world, the use of numbers to communicate mathematically, and the use of numbers in the development of mathematical ideas.

PERFORMANCE INDICATORS

2A. Use whole numbers and fractions to identify locations, quantify groups of objects, and measure distances.

2B. Use concrete materials to model numbers and number relationships for whole numbers and common fractions, including decimal fractions.

2C. Relate counting to grouping and to place value.

2D. Recognize order of whole numbers and commonly used fractions and decimals.

2E. Demonstrate the concept of ratio and percent through problems related to actualsituations.

INCLUDES

- Read and write whole numbers to hundred millions.
- Use ordinal numbers through 500th.
- Relate fractions and decimals to the monetary system and to metric measure.
- Identify use of fractions and decimal in daily life.
- Manipulatives: base 10 blocks, abaci, chip trading for place value in whole numbers and decimal fractions to hundredths.
- Odd and even numbers as a result of addition, subtraction, multipli-cation.
- Prime numbers.
- Skip counting.
- Various ways a figure can be divided into equal parts, using terms numerator and denominator.
- Order unit fractions and decimals and use < and > signs utilizing concrete materials.
- Find equivalent fractions.
- Number line and coordinates with positive and negative numbers.
- Place value concepts extended to millions and hundredths.
- Whole numbers to millions.
- Fractions with denominators 2, 3, 4, 5, 6, 8, 10, 12.
- Decimals to hundredths.
- Percents that are multiples of 5.
- Concept of ratio in real-world situations.

Key Idea 3

Operations

Students use mathematical operations and relationships among them to understand mathematics.

PERFORMANCE INDICATORS

3A. Add, subtract, multiply, and divide whole numbers.

3B. Develop strategies for selecting the appro-priate computational and operational method in problem-solving situations.

3C. Know single digit addition, subtraction, multiplication, and division facts.

3D. Understand the commutative and associative properties.

INCLUDES

- Addition and subtraction of whole numbers less than one million.
- Subtraction with zeros in the minuend.
- Multiply three-digit numbers by two-digit numbers. Multiplication by multiples of 10.
- Division of three-digit dividends by one- and two-digit divisors (quotient and remainder).
- Use diagrams, charts, and tables to help understand problem information.
- Use open sentences to model problems.
- Use commutative, associative, distributive, inverse properties.
- Look for patterns.
- Break problem into parts.
- Inverse relationships of operations.
- Special role of zero.
- Multiplication and division facts through 144.
- Application of identity elements of addition and multiplication in learning and understanding number facts.
- Commutative property: addition, multiplication.
- Associative property: addition, multiplication.

Missing Page

Key Idea 5

Measurement

Students use measurement in both metric and English measure to provide a major link between the abstractions of mathematics and the real world in order to describe and compare objects and data.

PERFORMANCE INDICATORS

5A. Understand that measurement is approxi-mate, never exact.

5B. Select appropriate standard and nonstan-dard measurement tools in measurement activities.

5C. Understand the attributes of area, length, capacity, weight, volume, time, temperature, and angles.

5D. Estimate and find measures such as length, perimeter, area, and volume, using both nonstandard and standard units.

5E. Collect and display data.

5F. Use statistical methods such as graphs, tables, and charts to interpret data.

INCLUDES

- Identify appropriate metric units for measuring the area, mass, perimeter, and volume of a variety of objects.
- Identify equivalent measures within the metric system of measure.
- Relate decimal concepts to metric measurement tools.
- Relate the clock face to fractions of a circle.
- Study time to five-minute, oneminute, and one-second intervals.
- Find the area and volume of specific figures by counting units.
- Explore connections between factors and multiplication facts and area and volume.
- Measurement problems related to other areas such as literature, science, and social studies.
- Select and use appropriate metric measurement tools.
- Compare equivalent measures within the metric system.
- Perimeter of polygons.
- Find the circumference of circles by measuring with string.
- Graphs of statistical data drawn from newspapers, magazines, polls, charts, surveys, etc.
- Make frequency tables from tallied data.
- Organize data with graphs, models, pictures, lists.
- Use concrete materials to develop the concept of average or arithmetic mean.
- Find the range and the mean in a collection of organized data.

Uncertainty

Students use ideas of uncertainty to illustrate that mathematics involves more than exactness when dealing with everyday situations.

PERFORMANCE INDICATORS

6A. Make estimates to compare to actual results of both formal and informalmeasurement.
6B. Make estimates to compare to actual results of computations.
6C. Recognize situations in which only an estimate is required.
6D. Develop a wide variety of estimation skills and strategies.

INCLUDES

- Rounding numbers, using number lines and measuring instruments (meterstick, thermometer).
- Estimate measurements before measuring.
- Estimate the outcomes of problems/ experiments, complete the task, and compare the results with the prediction.
- Explore the meaning of large numbers through such activities as esti-mating the grains of rice in a coffee can, the number of letters on a page, ways that newspapers report large numbers.
- Discuss real-world examples of when estimating would be accept-able and when it would not.
- Explore quantitative information that will help to relate personal experiences to the meaning of million.
- Round numbers to nearest tenth, whole number, hundred, and thousand.
- Develop a variety of strategies for estimating addition, subtraction, multiplication, and division.
- Develop a variety of strategies for estimating quantities.
- Develop strategies for estimating measurements.

Key Idea 6
Uncertainty
Continued

PERFORMANCE INDICATORS
6E. Determine the reasonableness of results.
6F. Predict experimental probabilities.
6G. Make predictions, using unbiased random samples.
6H. Determine probabilities of simple events.

INCLUDES
- Develop orderly ways to determine the number of possible arrangements and combinations (e.g., tree diagrams).
- Estimate the result of computations before using a calculator, especially in computations with decimals.
- Make generalizations about the difference between products of numbers greater than one and when one number is less than one.
- Estimation strategies for multiplication and division such as: when the divisor is greater than one, the quotient will be less than the dividend; and when it is less than one, the quotient is greater than the dividend.
- Conduct and predict outcomes of various experiments, using unequally as well as equally likely outcomes.
- Recognize events that are certain and events that have no chance of occurring.
- Explain why a game is fair or unfair.
- Collect statistical data from newspapers, magazines, polls.
- Use spinners, drawing colored blocks from a bag, etc.
- Explore informally the conditions that must be checked in order to achieve an unbiased random sample (i.e., a set in which every member has an equal chance of being chosen) in data gathering and its practical use in television ratings, opinion polls, and marketing surveys .
- Determine the number of ways an event can occur.
- Use fractional notation to express the probability of an occurrence .
- Explore problems that involve a systematic identification of ordered arrangements, using models, pictures, lists, or tree diagrams.

Patterns/Functions

Students use patterns and functions to develop mathematical power, appreciate the true beauty of mathematics, and construct generalizations that describe patterns simply and efficiently.

PERFORMANCE INDICATORS

7A. Recognize, describe, extend, and create a wide variety of patterns.
7B. Represent and describe mathematical relationships.
7C. Explore and express relationships, using variables and open sentences.
7D. Solve for an unknown, using manipulative materials.

INCLUDES

- Number patterns and sequences.
- Repeated patterns (abab, etc.).
- Design patterns.
- Use symbols <, >, £, •.
- Terms at most and at least.
- P resent division facts in more than one way, such as, 18 ÷ 3 = 18/3.
- Describe number sequences.
- Investigate relationships between addition and subtraction; addition and multiplication; subtraction and division; and multiplication and division.
- Relate fractional notation for tenths, hundredths, thousandths to decimal fraction notation.
- Consider, discuss, and predict whether the sum, diff e rence, or product of two numbers is odd or even.
- Relate area and volume formulas to counting squares or blocks.
- Solve open sentences with missing information.
- Use open multiplication and division sentences in situations of equality and inequality.
- Use formulas to find perimeter and area of geometric shapes.
- Use counters to solve division problems to find the number of groups possible when each group is a given size, and the number of objects in each group when the number of groups is known.
- Use counters to explore number pat-terns like triangular numbers and square numbers.
- Use counters to help solve problems that can be summarized with open sentences.
- Use counters to explore or explain commutative and associative properties of addition and multiplication.

Key Idea 7
Patterns/Functions
Continued

PERFORMANCE INDICATORS
7E. Use a variety of manipulative materials and technologies to explore patterns.
7F. Interpret graphs.
7G. Explore and develop relationships among two- and three-dimensional geometric shapes.
7H. Discover patterns in nature, art, music, and literature.

INCLUDES
- Use manipulatives or computer programs that allow students to manip-ulate geometric shapes such as tangrams and pattern blocks.
- Use manipulatives or calculators to skip count and relate to multiplication .
- Use manipulative materials and relevant computer software to explore symmetry.
- Use manipulatives or relevant computer software to explore linear patterns.
- Find mode, median, mean, and range of a set of data.
- Comp re frequencies within a bar graph or histogram.
- Describe trends in bar graphs and line graphs.
- Identify the geometric shapes of the faces of prisms, pyramids, cones.
- Identify diff e rent types of prisms and pyramids.
- Find two- and three - dimensional shapes in nature, art, and humanmade environment .
- Find examples of tessellations in the real world.
- Identify examples of symmetry in nature, art, and music.
- Relate the concept of fraction to beat value of notes in music (whole note = one beat, half note = one-half beat, etc.)
- Relate examples of children's literaure to mathematics for motivation, exploration, and problem solving.

How Instructional Packages Facilitate Academic Achievement

Instructional packages are multi sensory, self-contained teaching units that appeal to students who learn slowly or whose learning style characteristics respond to this method. All packages have certain basic elements in common;

1 Each package focuses on a single concept.
Whether the package deals with learning how to tell time, identifying adverbs and using them correctly, the division of fractions, or war as a human atrocity, students know precisely what the focus is and can decide if it is appealing as a new topic or useful in the reinforcing a previously learned skill. The cover and title always reveal what the package contains.

2 At least four senses are used to learn the contents.
A typewritten script that is repeated by he taped voice of the teacher gives clear directions to students to construct, manipulate, piece together, write draw, complete, play and in several ways use their sense of touch and their entire bodies in kinesthetic activities related to the package's objectives.

3 Feedback and evaluation are built in.
Tests are included in the package, and students may respond by writing, taping , or showing results. Correct answers and responses may be checked as the items to be learned are completed. The directions allow for immediate feedback ad self-evaluation. Mistakes can be corrected through repetition of the taped and printed directions and by comparing the student's answers with ones prepared fort the games and activities.

4 Learning is private ad aimed at individual learning styles.
Only the teacher and student know how well the youngster is doing. Self-image and success are enhanced as progress increases without peer competition for the slower students. The multi sensory approach; colorful materials and packaging; working alone ; motivating choices; selection of when, where, and how; and the ability to move about and to eat if necessary make the instructional package an effective teaching aid for many students.

Excerpt from Teaching Students Through Their Individaual Learning Styles: a Practical Approach by Dunn and Dunn

Examples of Appropriate Instructional Packages
(for elementary educational programs)

Language Arts: Parts of Speech, correct grammar, selected skills such as;

- Recognizing and using adjectives
- What does an adverb do?
- Knowing nouns
- When to use capital letters
- How to solve problems
- How to write and original ending
- How to follow directions
- The __________ word family
- Quotation marks: where do they go?
- How to develop complete sentences
- How to write a business letter

Social Studies: Map skills, geographical locations, community workers, common interests, such as;

- East and West
- Locating capital cities
- Games children play
- The energy crisis; How does it affect you?
- Customs of the Algonquins
- The Canadian Pipeline
- A different kind of key
- How climate affects industrial growth?
- What is a family?
- Say "hello" in many languages
- Third World nations
- How to cope with divorce in the family

Mathematics: Telling time, counting, explaining money, sets, shapes, or signs;

- Can you tell time by the hour
- Telling time by the half hour
- What is your time worth?
- All about triangles
- Going in circles
- How many ways can you form a group of ____?
- How much is a "quarter"
- Counting by five
- A "pair" is never lonesome
- "Stop" and "Go"
- A set of three "any things"
- Recognizing danger signs

Science: Explaining sources of power, food, growth and health;

- What can a magnet do for you?
- Making a bulb light
- What is a good breakfast?
- Let's have a party!
- Static electricity
- Are you a mammal?
- What can marijuana do for you?
- How wind works for us
- Would you like to make a bell ring
- How many ways does a tree grow?
- How to plant seeds
- Are your teeth falling out? they will!
- Which drugs can kill you?

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