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Mathematics and Visual Arts Education

Teaching and Learning Between the Lines

A line defies simple definition. Within mathematics, it has been described as a geometrical object having length but no depth or width formed by a straight set of points that extends to infinity in both directions, and as a set of the points whose coordinates satisfy a given linear equation on the Cartesian plane or in Euclidean space. In visual arts, the line has been referred to as a “basic element,” often defined as a continuous mark made on a surface. In art, a line may be straight, curved, bent, thick, thin, broken, vertical, horizontal, or freehand; it is a tool used to visually communicate patterns, two-dimensional shapes, and three-dimensional spaces or objects. The study and use of “line” has also formed a major component, with related skills, of both the mathematics and visual arts curricula in formal schooling.

Teaching and learning “between the lines,” metaphorically speaking, involves the recognition of this similarity and the celebration of this and many other connections that exist between these two rich disciplines. There are many



C1-1 Iris images repeated in various media (colour plate i)

reasons why it is beneficial to connect mathematical concepts with visual arts education. This chapter presents how individuals develop both mathematical and visual literacies, and how these two academic journeys can and do intersect and overlap. Herein we discuss teaching and learning theories and strategies that support learning experiences that explore in significant ways these important connections. These types of pedagogical approaches include constructivism, problem-based learning, interdisciplinary learning, brain-based learning, differentiated instruction, and universal design for learning. This chapter also highlights the positive and synergetic effects of integrating mathematics and visual arts on the overall educational experience of children. We briefly present how mathematics and art phobias, or anxieties, are perpetuated and what can be done to offset these negative realities for teachers, parents, and most importantly, students.

Two Significant Perspectives on the World

Why do many flowers have five or eight petals, but very few six or seven? Why do snowflakes have six-fold symmetry? Why do tigers have stripes but leopards spots? Throughout human history, artists and scientists alike have been inspired by the form and beauty of the natural world. Our changing vision of the universe, and of our place within it, reflects an ever-growing understanding of pattern and structure in nature. Human mind and culture have invented a formal system of reasoning that lets us recognize, classify, and exploit patterns, whatever they may be and wherever they arise. (Stewart, 1995, cover overleaf introduction)

According to Stewart, this formal system of reasoning is called *system mathematics*. Others have described the interpretation of the natural world as art, or aesthetic awareness. Are both types of perspectives possible, valid, and widely

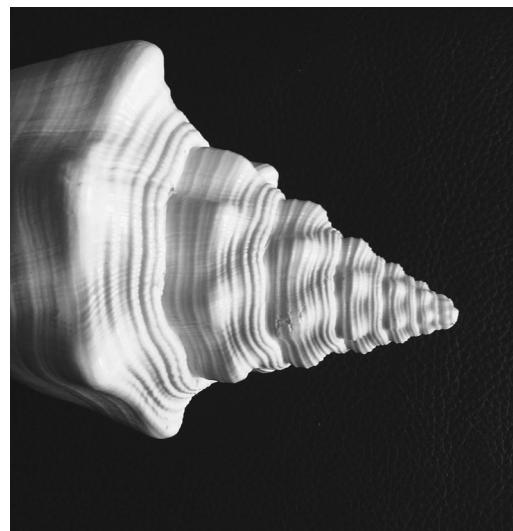
available? Doczi (1981) presents a less systematic approach to understanding the visual world, as characterized in the following aesthetically inspired description of similar natural phenomena:

Why do apple blossoms always have five petals? Only children ask such questions . . . When we look deeply into the patterns of an apple blossom, a seashell, or a swinging pendulum, however, we discover a perfection, an incredible order, that awakens in us a sense of awe that we know as children. (p. i)

Children enjoy exploring natural and human-designed environments through their senses of sight, sound, smell, taste, and touch. These experiences can teach a great deal about how and why things are put together. Children can learn about many mathematical concepts, as well as the elements of visual composition, or design, which comprise line, shape, texture, form, tone (value), and colour.



C1-2 Flowers with five petals (colour plate i)



C1-3 Seashell

These elements are to be found in natural forms such as bees' nests, sea-shells, spider webs, flowers, and bird wings, to name but a few. They are also the elements that have been mathematically organized into human-designed forms. For example, numbers and shapes were represented in the Lascaux paintings of early cave artists in France and Spain. They are, mathematically speaking, two-dimensional maps of objects in space; yet they are also historic and beautiful.

Some Historical Connections

Culture, Mathematics, and Visual Art

Many writers, scientists, and mathematicians give credit to the Egyptian, Greek, and Roman cultures for their strong influence on our present understanding of mathematics, art, and architecture. While there are obviously many contributions made by the above-mentioned cultures, some of which we shall highlight in this chapter, we also acknowledge that there are many Indigenous world cultures that have also demonstrated a strong understanding of mathematics in their writing, artworks, and built structures/environments.

Indigenous peoples have continually looked to nature for guidance and inspiration when creating images, functional forms, and architectural designs; hence a number of these connections will also be made explicit throughout the text within the descriptions of the various learning experiences. Ethnomathematics is a branch of mathematics education dealing with the study of the relationship between mathematics and culture (see, for example, D'Ambrosio (1985); Ascher (1991); Jarvis & Namukasa (2009)). In terms of the relationship between art education and culture, Freedman (1987) provides an expansive overview in her book *Art Education as Social Production: Culture, Society, and Politics in the Formation of Curriculum*.



C1-4 First Nations teepee (colour plate i)



C1-5 West Coast totem sculpture of human figure (colour plate i)

The Ancient Greeks

Mathematics and the visual arts have coexisted since the dawn of human history. Furthermore, beyond mere coexistence, they have been intricately interwoven through issues of form and function throughout every cultural era. In ancient Greece, sculptors such as Phidias, designer of the Parthenon frieze panels and the monumental ivory and gold statue of Athena for which the temple was built, used the *golden ratio* extensively in their work. This mathematical proportion was believed by the Greeks to hold



C1-6 Greek Parthenon (colour plate ii)

the profound secret of visual harmony in the universe. The legacy of this concept, which would later be referred to as the “divine proportion” during the Renaissance, is still evident in both modern and postmodern styles of architecture and fine art. Alex Colville, one of Canada’s most widely recognized artists and who has used the golden ratio in his compositions, described the aesthetic experience involved:

Once you begin to perceive these relationships, circles, spirals, triangles and rectangles appear as if on their own. The beauty of it comes as a surprise, and its harmonies inspire joy. Part of the excitement is that these discoveries, though new to us, are about immutable laws that have been in force since time and space began. (cited in Fry, 1994, p. 35)

Throughout history, artists have made use of many other mathematical elements, including “the geometric shapes, symmetry, the earth’s measurements, the proportions of humankind, the patterns of the stars, conic sections [circle, ellipse, parabola, hyperbola], as well as the computer” (Attenborough, Pattison, Patsiatzis, & Muller, 1997). Newman and Boles (1992) maintain that although these two disciplines are often viewed as polarities, they are in fact “the left and right hand of cultural advance: one is the realm of metaphor, the other, the realm of logic . . . Our humanness depends upon a place for the fusion of fact and fancy, emotion and reason. Their union allows the human spirit freedom” (p. xiv).

Socrates, Plato, and Aristotle represent a rich lineage of effective pedagogical transfer. All three of these teachers held to strong, but distinct, educational philosophies. Socrates, master of the strategic question-and-answer method that bears his name, was convinced that education and healing were closely related, and therefore defined teaching as the “building, in a pupil, of a system of value priorities and preferences that defined the healthy soul” (Broudy & Palmer, 1965). Socrates was also one of the first Western educators to hold the belief that unless citizens had an understanding of art and music, they were not considered to be adequately educated (Naisbitt & Aburdene, 1990). In *The Republic*, Plato, using his metaphor of the divided line, describes four “states of mind” or “ways of knowing.” The lower levels of illusion (*eikasia*) and belief (*pistis*) encompass the “distorted perceptions” found within poetry and art (trans. 1955/1987, p. 316). To the third level of reason (*dianoia*) belong mathematics and the sciences. “For Plato the study of mathematics was to shape the soul, just as music and literature shape the soul” (Broudy & Palmer, 1965, p. 44). Only at the fourth and highest level, known as intelligence (*noesis*), is the clearest mental vision and recognition of truth achieved through dialectic (pp. 41–42).

Whereas both Socrates and Plato acknowledged the important, yet separate and unequal, emphases on mathematics and education in the arts, it was Aristotle, the most prized student of Plato’s Academy, who is remembered for encouraging the cognitive “search for relationships between things apparently disconnected”

(Newman & Boles, 1992). And so, it is this latter quest, no doubt influenced in part by his predecessors and their teachings, that bears directly on an integrated approach to the two disciplines.

For the Greeks of the ancient world, much of their mathematics dealt with geometry (a word derived from “land measure”), a topic that had been explored by and learned from the Egyptians. Euclid of Alexandria, often referred to as the “father of geometry,” founded a school in the Hellenistic period and collected many of the then-existing mathematics manuscripts into a carefully organized, thirteen-volume set known as *The Elements*. This popular text would be widely consulted by mathematicians for the next 2,000 years.

Finally, one would be remiss in discussing Grecian influence on interdisciplinary education without mentioning he who has been referred to as the father of both mathematics and music, Pythagoras. It was his passionate quest for learning in many different areas that inspired his disciples to become members of his covert mathematical brotherhood and to continue in his pursuits after his death. Many of the philosophical, mathematical, and aesthetic pursuits of the ancient Greek culture would be revisited and expanded over a thousand years later during the European Renaissance.

The Renaissance

The rebirth of culture and learning that pervaded Europe during the Renaissance was intrinsically tied to the notion of the individual as brave and enlightened adventurer. This social metaphor had, of course, its literal parallels in the likes of explorers Columbus and Magellan, who actually crossed unknown waters in search of the affluent Far East and international glory. But perhaps more fascinating still was the emergence of the artist/scientist who pushed the known boundaries of learning and discovery to new limits. De La Croix and Tansey (1986) highlight this phenomenon:



C1-7 Raphael's *The School of Athens* (colour plate ii)

The wide versatility of many Renaissance artists—like Alberti, Brunelleschi, Leonardo da Vinci, and Michelangelo—led them to experimentation and to achievement in many of the arts and sciences and gave substance to that concept of the archetypal Renaissance genius—*l'uomo universale*, “the universal man.” (p. 524)

One such man was the artist Raphael. In his large oil painting *The School of Athens*, Raphael visually demonstrated the historical connections between the arts and the sciences by juxtaposing a number of great philosophers, artists, and mathematicians of different eras. This was meant to symbolize the new and expansive learning of the Renaissance. Included in his academic fantasy scene were Plato, Aristotle, Pythagoras, Euclid, Leonardo da Vinci, his contemporary hero Michelangelo, and an unobtrusive self-portrait.

In 1983, IBM Canada was involved with the development and sale of an educational packet entitled *I, Leonardo: A Journey of the Mind*. This extraordinary initiative included a video of historical reenactment, a filmstrip, audiotape, time charts, student handouts, suggested projects, and a teacher guide. Also in the kit was an introductory letter addressed, most unusually, to the “Science or Art Department Head,” and which included the following paragraph:

Most recent studies of Leonardo have continued the tradition of focusing on a single aspect of his multi-faceted character: Leonardo the artist, the scientist, the engineer, the city-planner, the architect. “I, Leonardo” attempts to place all these achievements within an interrelated framework; to explain how, for example, Leonardo’s observational skills, developed through his work as a painter, extended his scientific insight, and how his scientific investigations enhanced his work as an artist. (1983)

This corporate endeavour not only highlighted the historical connections between mathematics and visual arts, but it also served as a tangible example of how curriculum can be successfully integrated within an interdisciplinary context, using a historical character as a springboard for learning.

The Modern and Postmodern Eras

The last two centuries have seen support for an integrated curriculum wax and wane. A well-rounded European liberal arts education in the 1800s would certainly have involved exposure to art and music as well as to the scientific disciplines (Naisbitt & Aburdene, 1990). While some would argue that mathematics (or the sciences in general) has influenced the visual arts (Dorn, 1994; Golen, 1999), others would maintain that the preponderance of human experience shows the relationship to be vice versa (Shlain, 1991). Dorn (1994) builds a strong case for the arts being heavily influenced by mathematics:

In art, the twentieth century was a time when: (a) Einstein's discoveries of relativity and of the space-time continuum affected the way space was ordered in painting; (b) Marx's political thought and Freudian psychology radically influenced its form and content; and (c) the positivist ideas of Wittgenstein and the anthropological views of Levi Strauss inspired new uses of language and ritual now seen as the basis for the revisionist and the deconstructivist art of today. (p. 36)

Shlain (1991, p. 19) hypothesizes that "repeatedly throughout history, the artist introduces symbols and icons that in retrospect prove to have been an avant-garde for the thought patterns of a scientific age not yet born." He supports this notion through examples from history, and interprets the major metaphysical blurring between the disciplines as follows:

While art is thought to be relatively subjective, physics, until this century, scrupulously avoided any mention of the inner thoughts that related to the outer world. Physics concerned itself instead with the objective arena of motion, things, and forces. This stark difference between art and physics blurs in light of the startling revelations put forth by the quantum physicists that emerged from the fusion of the contradictory aspects of light.... Thus "subjectivity," the anathema of all science (and the creative wellspring of all art) had to be admitted into the carefully defended citadel of classical physics. (p. 23)

Still other theorists, such as Vitz and Glimcher (1984), have proposed a "theory of parallelism," in which the advances in both the sciences and the arts are often correlated through simultaneous expressions of perceived reality. They state the following:

These similarities cannot be treated as accidental because, as it will be shown, often the two works occur at about the same time, and frequently the

artist's comments make it clear there was influence from visual science or that the artist on his own had discovered the same visual phenomena that contemporary scientists were investigating. Thus, it is argued that the artists' and scientists' parallel conceptual approach to vision frequently resulted in the construction of pictorially similar or even identical works. (p. 37)

Griffiths (2000), in his intriguing paper, "Mathematics at the Turn of the Millennium," describes the dual nature of mathematics, regardless of mutual influence or chronology:

Indeed, the mathematician G. H. Hardy once said that the practice of mathematics can be justified only as an art form. In fact, there is a parallel with the arts here. Mathematicians, like artists, rely heavily on aesthetics as well as intuition, and it is not uncommon to solve problems while taking a shower or a walk. But with respect to utility, the argument in mathematicians' favor is a strong one. . . . Thus mathematics has a dual nature: it is both an independent discipline valued for precision and intrinsic beauty, and it is a rich source of tools for the world of applications. And the two parts of this duality are intimately connected. (pp. 4-5)

The connections between mathematics and visual art have been nowhere more apparent than in the visible works of art and architecture that combine the two disciplines in both physical and conceptual ways. A list of pertinent artists and architects from the last two centuries would include, among many others, Le Corbusier, Gropius, Escher, Stella, Calder, Moore, LeWitt, Dali, Duchamp, Collins, Mondrian, Silverman, Verhoeff, Colville, and Pollock.

Throughout the course of human history—beginning in ancient Aboriginal cultures, extending through Babylonian, Egyptian, Greek, Roman, Medieval, and Renaissance periods, and continuing on in the modern and postmodern eras—the disciplines of mathematics and visual art have been fused in theory, in edu-



C1-8 Maori tiki

tion, and in the making of images and structures. Integrated learning experiences—whether they are single activities, projects, or extended curriculum—serve to reinforce these chronological connections as students experience an age-old approach to rich learning and application.

Objectives of Exploring the Math and Art Connection

The efforts in developing this book were to create/highlight connections between the two traditional disciplines of mathematics and visual arts by way of rich “Learning Experiences.” Furthermore, by engaging with this text, teachers should expect that their students will

- ❖ Increase their understanding of art education’s elements and principles of art/design, or composition, and of mathematical concepts, many of them pertaining to geometry;

- ◆ Develop math and art vocabulary, related understanding, and the ability to discuss;
- ◆ Develop a more acutely sensitive visual awareness of natural and human-designed objects and environments (e.g., describe, identify, classify, copy, reinvent);
- ◆ Create unique, personal artistic statements through drawing, painting, sculpting, assemblage, and digital production using a variety of materials and by applying mathematical concepts;
- ◆ Develop a greater overall appreciation of both mathematics and the visual arts;
- ◆ Develop the capacity to view mathematical phenomena through an aesthetic/artistic lens, and to view artistic works through a mathematical lens (i.e., different literacies); and
- ◆ Improve attitudes towards their abilities in mathematics and in creating works of visual art (i.e., decreasing any existing phobias/anxieties relating to these subjects).

Math and Art Phobia

Math Phobia

Math phobia is real. It creates a barrier that lies between the student and the learning of mathematics. Early attention must be paid to reluctant and fearful mathematics students. If their fear is not addressed, this barrier grows. My students showed me that a vital key to successful intervention lies in the emotional realm. A teacher must create a safe atmosphere and encourage students to share openly these feelings; all must work together to create this safe place. (Blomfield, 2000, p. 7)

Math phobia or anxiety has been defined as a state of discomfort that occurs in response to situations involving mathematical tasks that are perceived as threatening to self-esteem. It can be experienced as outright fear, intense negative emotions, or other physiological reactions to anything remotely mathematical (Austin, Wadlington & Bitner, 1992). These feelings of anxiety can lead to panic, tension, helplessness, fear, distress, shame, inability to cope, sweaty palms, nervous stomach, difficulty breathing, and loss of ability to concentrate (Posamentier & Stepelman, 1990). Also, according to McCoy (1992), math anxiety is most prevalent among tactile-kinesthetic learners.

The reasons for math anxiety in teachers may include negative math attitudes adopted by their parents and former teachers, inadequate math training backgrounds, and/or lack of general mathematical understanding. Math anxiety may inhibit teachers from acquiring requisite math skills and processes needed to teach children. Research supports the idea that some teachers may transmit their undesirable attitudes and anxiety toward mathematics to their students. Teachers who are ill-prepared or anxious about mathematics tend to use more traditional teaching methods such as lecture, paper-and-pencil worksheets, reliance on rote memory, neglect of developing reasoning or estimation abilities, and the inadvertent creation of a non-participatory classroom. They tend to concentrate on teaching basic skills and concepts with an emphasis on drill-and-practice without necessarily promoting understanding (Fiore, 1999; Selke, 1999).

This is contrary to the current reform-oriented movement toward teaching mathematical concepts and problem solving through cooperative learning and projects (National Council of Teachers of Mathematics, 2000). Elementary school teaching not only requires the teacher to know and understand mathematical content, but a growing body of research has shown that there is a unique and important set of pedagogical skills/thinking referred to as “mathematics knowledge for teaching” (Thames & Ball, 2010), which enables mathematics teachers (i.e., specialists) and teachers of mathematics (i.e., generalists) to teach more ef-

fectively by seeing connections between math strands; recognizing common student misconceptions and remediating accordingly; and carefully interpreting multiple solution strategies shared by students in class.

There is more to real life than rummaging around the kitchen cupboards to find the volume of the Twinkies box or the can of Ravioli. We must distinguish between using things in the world around us to do math upon, and using math to understand the world around us. One is deceitfully artificial, a straw man. The other is transformative, for it encourages people to think, and perhaps to intervene. (Stocker, 2007, p. 48)

Mathematical modelling (representing real-world situations or data using graphs or now easily accessible, powerful software programs) is encouraged as a way of interpreting and representing the world in which the child lives, and of solving related problems that may be of interest to the student or to the entire class.

Art Phobia

Visual art can be viewed as a language that is learned, not unlike reading, speaking, mathematics, music, and movement. Children tend to proceed through developmental stages in visual arts communication. They develop skills in representing their world and expressing their thoughts in two and three dimensions. Children may have different reasons for being interested in visual art (e.g., natural curiosity regarding image making; formal instruction by adults), but all tend to move through stages as they progress physically and intellectually. Unfortunately, many children stop their artistic development at about age ten to twelve years, when the deep desire for realistic drawing ability is not satisfied by their teachers, in terms of classroom instruction. The ability to see, interpret, and create art images is not merely intuitive; rather, it is a learned

Mathema Anathema

Mathema anathema,
A phobia severe!
That vile, loathsome topic,
Which returns to haunt each year.
Mathema anathema,
The c(o)urse one loves to hate!
Its shadow darkens every school;
A nemesis of fate.
Mathema anathema,
Like words of ancient chant;
Resounding through the centuries;
A cry from all who “can’t.”
Mathema anathema,
Perhaps there be a cure;
If math was simply relevant,
And fun, one could be sure, that...
Mathema anathema,
Would all but disappear,
As interesting lessons,
Now dispel the former fear!

Jarvis 1997

Artifex Ad Artifice

Artifex ad artifice,
The wonder drug of art!
That warm and fuzzy topic,
Which caters to the heart.
Artifex ad artifice,
The course one hates to miss!
Reward for good behaviour,
Is mindless Friday bliss.
Artifex ad artifice,
‘Tis sophistry supreme;
The students colour picture books,
And leaf through magazines.
Artifex ad artifice,
Perhaps there be a cure;
If art was simply relevant,
And meaningful, then surely...
Artifex ad artifice,
Would all but disappear,
As synthesis builds competence,
For expectations clear.

Jarvis 2000

ability (Edwards, 1999; Hoffer, 1977). As children enter their pre-adolescent years, they may become critical of the art they create and lack confidence in their own art making. Throughout the developmental stages, children need encouragement and good teaching. It is important that teachers discover where students are positioned, developmentally speaking. They need to support the children in their artistic efforts. The teachers need to become aware of, and avoid, art experiences that may be detrimental (Naested, 2010).

Teachers with art phobia, or anxiety, generally have a poor self-concept relating to their own art ability. They often lack knowledge and understanding of the design elements and principles, art vocabulary, techniques, and the history of art. These teachers may also tend to rely on planned or overly scripted art experiences that may in fact be detrimental to their students' visual art development (e.g., having their students do cut-and-paste activities, complete colour-by-number pictures, or reproduce "craft work").

Why Connect Art and Mathematics?

Distinct, separate subjects of mathematics, science, language arts, music, and visual arts were created artificially by educators, probably for efficiency in curriculum design and teacher planning. But humans do not live in a real world in which subjects are separate. We have perhaps forgotten the natural connections between the subjects. Within the content of this book, we will be stressing teaching strategies and learning experiences that seek to connect visual art and mathematics, and thereby increase student understanding and confidence. These learning experiences are created and presented in such a way as to, wherever possible, honour the integrity of both disciplines, understanding that certain activities may have more of an art or a mathematics emphasis.

Visual Perception in Art and Geometry

Students' visual discrimination and depth perception develop at different times and at different rates, as does their visual-motor coordination. These factors affect the way students interpret and create visual art and two- and three-dimensional geometric images, and may also influence their ability to learn geometry. "If the students are having trouble with visual perception, they will probably experience frustration and failure when trying to recognize pictures and patterns

in geometry" (Hoffer, 1977, p. 85). Students who are experiencing difficulty in observing and drawing images of objects need to be guided through observation exercises that have them look more closely to fully grasp the details of the object. This requires careful observation, detail-by-detail, and hand-eye coordination (Jarvis, 2010; Naested, 2010).

Geometry deals with the properties and relationships of points, lines, angles, surface and solids. There are many concepts in geometry that cannot be recognized or understood, unless the students can visually perceive examples and identify figures and/or properties by associating them with previous experiences. Many geometrical concepts require a visual interpretation as problems are viewed or drawn on paper. (Hoffer, 1977, p. 89)

Depth perception is a developed and learned ability to understand two- and three-dimensional images and objects. It includes figure-ground perception, which is the ability to distinguish the foreground from background, and understanding of objects' position in space, or within spatial relationships. Teachers can plan learning experiences to assist students in developing body orientation through movement in dance, drama, and art. They can develop lessons that require students to learn kinesthetically through constructing, manipulating, carving, drawing, or painting. Visual discrimination is the ability to distinguish similarities and differences between objects. Students learn visual discrimination in relation to colour, shape, size, and thickness by creating objects in two and three dimensions. The learning experiences in this book are designed to assist in the development of both depth perception and visual spatial operations.

Learning Theories that Support an Art and Math Connection

Perhaps the two most exciting areas in contemporary education are human brain research and advances in new technologies. The past two decades have seen

tremendous growth and achievements in both of these areas, and these developments have significantly affected education at all levels and continue to do so. We know from brain research that when new knowledge is connected with prior knowledge we tend to understand better, and remember more thoroughly. When we are actively involved in our learning (e.g., constructivism), rather than passive listeners, we benefit from deeper understanding. Furthermore, when we are empowered to select elements of our own learning experiences (choice), the ways in which we learn (differentiated instruction), and to present our new learning to others (communication/teaching), the gains are even more dramatic. We also understand that there are many learning theories that support artistic and mathematical understanding. In the following, we provide short descriptions of a few of these theories.

HEMISPHERIC SPECIALIZATION is a learning theory that suggests that individuals develop a left- or right-brain dominance. The right side of the brain is credited with specializing intuition, spatial relations, and creativity, and the left side is credited with verbal and mathematical ability. In light of this learning theory, connecting art and math experiences will address and develop both sides of the brain (Edwards, 1999).

AUDITORY, VISUAL AND KINESTHETIC LEARNING THEORY was developed by Dunn and Dunn (1978). The auditory learner learns best through words and learning experiences that include talking, group discussion, listening, singing, and listening to music. The visual learner learns through images and learning experiences that include viewing, imagining, reading, drawing, constructing, writing, looking at pictures and creating models or diagrams. The kinesthetic learner learns best through movement and learning experiences that include doing, touching, manipulating, constructing, drawing, and painting. Art and math learning experiences that are connected assist students with these different learning styles.

Howard Gardner (1983) developed the THEORY OF MULTIPLE INTELLIGENCES based on the premise that we have historically viewed intelligence too narrowly. Initially he identified seven intelligences: logical-mathematical, verbal-linguistic, musical, visual-spatial, bodily-kinesthetic, interpersonal and intrapersonal (note: Gardner has subsequently added an eighth intelligence: naturalistic). Visual art and mathematics learning experiences can be developed to address these different types of learning styles.

Visual art experiences develop visual literacy and visual awareness. One important aspect of experiencing and understanding principles of art/design is that students can gain the benefit of more perceptive vision. Likewise, the term mathematical literacy has also become popularized (in preference over “numeracy,” which often emphasizes arithmetic/numbers), wherein students become proficient at mathematical skills and problem solving, and grow to view and understand their world with a mathematical perspective.



When I was a child,
I played as a child.
When I became a student,
I was encouraged to put away my childish ways,
And decipher meaning from the world through
word and number.
When I became a teacher,
I rediscovered the values of play,
And other ways to experience and learn.

Naested, 1991

C1-9 The joy of making lines and images as a child (colour plate ii)

Teaching and Learning Strategies

Tell me mathematics and I forget; show me mathematics and I may remember, involve me . . . and I understand mathematics. If I understand mathematics, I will be less likely to have math anxiety. And if I become a teacher of mathematics, I can thus begin a cycle that will produce less math anxious students for the generations to come. (Williams, 1988, p. 101)

Williams (1988) paraphrases a Chinese proverb to illustrate what teachers should do to assist students in understanding mathematics—this is the same for understanding visual art and the art process. Teaching strategies in reform-based mathematics classrooms should include small-group collaborative work, the use of manipulatives and visual aids, the use of real-life examples meaningful to the learner, and the development of spatial reasoning through observing, interpreting, understanding, and appreciating our inherently geometric world (National Council of Teachers of Mathematics, 2000). Teachers should facilitate problem-based activities that involve problems and projects that connect mathematics to other subjects and to the “real world” (Jarvis, 2008). Selected theories that assist the teacher in addressing pedagogical approaches that support learning, and that connect visual arts and mathematics, are summarized below. Some of the following names, terms, and definitions have varied over time. Teachers wishing to adopt particular approaches in their pedagogy are encouraged to further research these ideas.

CONSTRUCTIVIST APPROACH: Constructivism is an approach to teaching and learning that encourages learners to take an active role in their learning and construct new knowledge based on prior understanding. “Constructivist classrooms help young people to make sense of their world through actively acquiring, building, and understanding meaning and knowledge in social contexts” (Naested,

Potvin & Waldron, 2004, p. 84). This is closely associated with “active learning theory” and “discovery learning” literature. The premise here is that learners who are actively engaged (cognitively active) in a problem or process are more likely to recall information and/or to solve the problem at hand.

PROBLEM-BASED LEARNING (PBL): PBL was originally developed in the 1970s by a medical professor, Dr. Howard Barrows, at McMaster University in Ontario, Canada, for training medical students using a problem-based approach (Delisle, 1997). PBL features learning that is based on challenging, open-ended problems; often involves students working in collaborative groups; and usually finds teachers assuming the role of “facilitator” of learning, rather than disseminator of knowledge. Students make decisions within a prescribed framework around a problem or challenge, but students often design the process and are responsible for accessing and managing the information they gather. A final product or solution to the problem is evaluated with respect to the process (solution strategies) and the outcome (answer/conclusion). This approach is closely related to “inquiry-based learning” in which learning is based on students’ questions (i.e., often a problem of their choosing or their own creation). “Inquiry teaching puts students in the position of researchers, asking and answering questions about information that may range far beyond the boundaries of a single discipline” (Clarke & Agne, 1997, p. 30).

INTERDISCIPLINARY MODEL: The principal aim of integration or interdisciplinary instruction is to present learners with an opportunity to discover relationships that go beyond separate disciplines and that bind together different aspects of our world in some systematic manner (Naested, 2010). This is closely related to “integrative curriculum.” Beane (1993) suggests that genuine learning occurs as people “integrate” experiences and insights into their scheme of meanings and the most significant experiences are those tied to exploring questions and concerns that learners may have about themselves and their world.

BRAIN-BASED LEARNING: Neuroscientists such as Jensen, Sywester, Sternberg, Sprenger, D'Arcangelo, and others have written about learning and the brain. According to Jensen (1988), "learning changes the brain because it can rewire itself with each new stimulation, experience, and behavior" (p. 13). The brain adapts and rewires itself. Learning something new, doing something new, listening to something new can stimulate the brain. "The key to getting smarter is growing more synaptic connections between brain cells and not losing existing connections" (p. 15).

DIFFERENTIATED INSTRUCTION (DI): This approach to learning acknowledges the fact that students are at different developmental levels within a given discipline such as mathematics, and that students learn best in different ways. While DI certainly has its roots in frontier one-room schoolhouses in which learning was differentiated (at least by grade level) by necessity, it has been widely popularized by learning theorists such as Carol Ann Tomlinson (1999), who has created an effective model for analyzing factors affecting DI implementation. Canadian Marian Small (2008) has provided the related concepts of "open and parallel tasks" in mathematics instruction, which allow for multiple entry points, multiple versions of problems, and student choice based on their own perceived abilities and readiness.

UNIVERSAL DESIGN FOR LEARNING: This is an educational framework that appears to incorporate or integrate many of the key concepts of the previously mentioned frameworks. The early frameworks for universal design for learning (UDL) focused on students with disabilities or those learning English as a second language, and often included applied special technology. Some ways to integrate the principles of UDL in teaching and learning include using multiple ways of presenting information to address different levels of abilities and learning styles, providing students with choice (content, material, presentation of learning), and incorporating curriculum integration or overlap and continual assessment or feedback.

TEACHING AND LEARNING FOR THE iGENERATION: With the advent of new high-speed Internet technologies in the late twentieth century, access to information, images, open-source software (e.g., Google Art Project, Wikipedia, GeoGebra), and social networking tools (e.g., Facebook, Twitter) have opened up huge new areas and methods for student research and collaboration, making the integration of disciplines such as mathematics and visual arts even more intriguing. Web. 2.0 is a term used to describe how web applications facilitate information sharing, interaction, and collaboration on the world wide web.

Planning Rich Learning Experiences

Over the centuries, a disconnect in public opinion has arguably developed between art and mathematics, causing a commonly perceived disassociation between the two disciplines. While historically the number of artists/mathematicians who well understood the existence and richness of this math/art connection has been relatively small, a growing number of artists and teachers are becoming more aware of this connection. This book will attempt to expand the reader's understanding of both the natural and the built/created connections between visual art and mathematics. Furthermore, it will seek to promote the idea that while visual art images/objects can be interpreted through a mathematical lens; the corollary is also true, in that mathematical or scientific phenomena can be interpreted through an artistic, or aesthetic, lens. In Chapter 1, we contend that as these ways of seeing and interpreting the world are honed and deepened, students can significantly increase their own confidence in their mathematics and visual arts knowledge and abilities, as well as stimulating critical thinking and creativity across all learning domains and pursuits—a pattern that hopefully will continue throughout life.

In Chapter 2, we provide the reader with some general context by highlighting basic vocabulary and concepts traditionally found within the disciplines of

mathematics and visual arts. In Chapter 3, we present a series of learning experiences that focus on the math/art connections found within various forms of flora, or naturally occurring plants, trees, and vegetation. Chapter 4 extends this exploration to include learning experiences that focus on the fascinating world of fauna, or living creatures of the land, sea, and skies, that share our planet.

Historically, the natural connections of mathematics and visual art appeared to begin as people developed measurement systems based on the human body and other natural phenomena. Notable artists such as Vitruvius, Michelangelo, da Vinci, Dürer, Rembrandt, and Giacometti developed measurement systems to describe lengths and quantities by using body parts, such as fingers and hands, and using body movements to measure pacing. The understanding of the human body and appendages, along with the related study of proportion, greatly assisted the artist and the engineer in working with natural and human-designed objects and environments such as those created by architects like Ictinus, Callimachus, Phidias, and Le Corbusier. Chapter 5 examines mathematics and visual arts learning experiences relating to the human figure, and Chapter 6 features activities based on human-designed environments such as buildings and cities.

In Chapter 7, we turn our attention to learning experiences that involve connections between mathematics and visual art that relate to designed objects and games. Finally, in Chapter 8, we discuss how curricular integration can be implemented within a single lesson, an extended project, or a unit of study. We further provide a set of helpful appendices that comprise a glossary of key mathematical terms, a glossary of key visual arts terms, two sample extended projects, and a list of other related print and online resources.



C1-10A Drawing the train



C1-10B Painting the train (colour plate ii)



C1-10C Contextualizing the train