Functional Art and Water Science

By West Marrin
Guest Contributor

Recent interest in science-art collaborations seems to have focused on how artists can benefit from technological advancements in creating their works and how scientists can use the graphic arts to more effectively display their data. But interactions between science and art can extend beyond these established exchanges through functional art. Historically, functional art has referred to useful creations such as furniture, dishes, and lighting fixtures. More recently, functional art has appeared in the digital realm as infographics, visualizations, and interactive displays.

The physical, chemical, biological, architectural, musical, and artistic worlds are replete with examples incorporating identifiable patterns, rhythms, networks, and fractal-like relationships. In the field of water science, specifically, there is a fertile ground for physical and digital art to serve a functional role in researching, understanding, and providing practical design.

From "Drifters Project" by Pamela Longobardi. Image courtesy the artist.

Ocean Plastics: Artist Pamela Longobardi has documented and cleaned up plastic wastes on coastlines throughout the world. Her "Drifters Project" focuses on global-scale patterns created by the oceanic transport and deposition of plastics along the world's beaches. One facet of her art involves the use of selected plastic wastes to produce installations and exhibits that symbolically focus viewers' attention on the destructive usage and disposal of plastics. Possessing a scientific background, she approaches each site as a forensic researcher in distinguishing variations in the type and distribution of plastic materials that reflect their transport dynamics and pathways. The patterns of beach deposition can assist scientists, but are still unknown for many coastal areas.

Marine Habitat: Artist Mara Haseltine has created artificial reefs and other underwater habitats based on the geometry, patterning, and functionality of natural reefs in order to facilitate the reintroduction of marine organisms. In addition to structure, she has experimented with various materials (e.g., glass, metal, porcelain) in selecting the optimal substrates for the colonization of marine organisms. Particularly interesting is her use of nature's microscopic structures and patterns to create macroscopic designs, such as incorporating the pattern of fish gills in building artificial habitat structures for oysters. Her artwork serves a valuable scientific purpose in uniting cultural and biological evolution through so-called geotherapy.

Wave Rhythms: Researchers are now able to transpose the vibrational signatures of chemical mixtures, marine algae, and even DNA molecules into the hearing range of humans to create "nature-based" music. A functional form of this music was composed from the sonification of ocean wave dynamics, which created audible versions of the graphical data and revealed nuances that were not visible in the graphics alone. Composer Bob Sturm mapped the temporal spectrum of ocean buoy data, characterized by the infrasonic frequencies (0.025 to 0.058 hertz) of ocean waves, into the audible frequencies (20 to 20,000 hertz) for humans. In doing so, he was able to produce stereo sonifications by using the various wave directions.

Warkawater. Photo courtesy Architecture and Vision.

Water from Air: As sources of high quality freshwater become increasingly scarce, recovering atmospheric water has captured the attention of engineers and designers alike. Two visionary architects, Arturo Vittori and Andreas Vogler, have created a passive water collector (i.e., no energy required to operate) composed of a nine-meter tall bamboo framework supporting a specialized fabric on which the nighttime fog condenses. Catching and accumulating potable water is a function of Warkawater's geometry and fabric pattern. It was modeled after a native tree in Africa, serves as an artistic feature and gathering place for the community, and can be assembled by local people using simple tools.

Artificial Watersheds: Water and ice in the form of rivers, oceans, and glaciers have cut through the planet's surface in ways that create landscapes that have been captured in various forms of digital artwork. Recent interest in emulating these natural patterns to design sustainable and eco-compatible creations (e.g., green roofs, artificial wetlands) relates to their influencing hydrologic regimes, temperature dynamics, and aesthetics of a landscape. Perhaps the world's most famous green roof lies atop the School of Art, Design & Media at NTU in Singapore, where the top of a five-story building serves as a gathering place for students, blends seamlessly into the surrounding topography, insulates the entire structure, and harvests rainwater for irrigation.

Water Flowforms: So-called water flowforms are constructed with different shapes, lengths, materials, and designed flow rates. Cascading down a stair-stepped series of vessels, the water vortices possess distinct patterns and rhythms that are evident in the designs of John Wilkes. Once considered strictly architectural features, flowforms were studied by a group of European naturalists who observed that water exiting these structures sometimes displayed properties slightly different from water entering them. While the mechanisms underlying such changes have not been described, flowforms are reportedly used to treat wastewater and irrigation waters.

The Blue Marble: The role of photographs in shaping people's views of Earth is increasingly important, and some people contend that such images are less prone to dualistic interpretation than are scientific or theoretical portrayals. Dualistic interpretations are those that separate nature from humans in presenting environmental issues. The famous blue marble photo taken in 1972 by Apollo 17 astronauts arguably captured humanity's attention more than any other. In doing so, it transcended political boundaries, man-made patterns, and the illusion of a terrestrial planet.

Aquifer Billboards: An international design award was recently presented to artist Richard Vijgen, who mounted an electronic display of images from NASA's Gravity Recovery and Climate Experiment (GRACE) in the midst of New York's Times Square for an entire month. GRACE consists of two satellites that track fluctuating groundwater levels worldwide on the basis of small gravitational changes. Perceptions gained from this type of public art and graphic design permit people a real-time recognition and visualization of how climatic and hydrologic patterns (both spatial and temporal) directly influence the water beneath their feet.

A Water Wheel: The Los Angeles River was once a source of water for local residents, but is now just a concrete flood control channel. Artist Lauren Bon of Annenberg's Metabolic Studio has received approval to construct one of the nation's largest waterwheels on a section of the river as a tribute to the many waterwheels of the 1800s. In addition to its artistic and historic significance, La Noria will actually deliver treated water to feed a small stream and to irrigate a large park located along the river. The waterwheel is part of a revitalization plan to restore riverine habitats and to draw attention to LA's dependence on scarce water resources.

Personal Water: Whereas the use of patterns and rhythms to communicate art, music, or dance is relatively straightforward, the use of spatial or temporal patterns to represent scientific data is not. Fernanda Viegas and Martin Wattenberg create data visualizations, such as their wind map, using patterns and layers that feature entry points for viewers, thus facilitating both their interest in and understanding of data via social, personal, or emotional relevance. The California Water Foundation enlisted the assistance of a software company to visualize household water use patterns, which are compared to those of similar households as a means of contrasting temporal and spatial data and of enticing people to compete with each other in reducing water use.

Image courtesy NASA Johnson Space Center.

Planetary Images: NASA's Applied Sciences Program displays satellite images of earth in a recent art book, *Earth as Art*, prompting people to look more closely at the earth and to ask themselves how nature was able to create such intricate patterns. The colors in every image are spectacular as a result of computer enhancements that highlight specific wavelengths of emitted light—the majority of which are not otherwise visible to humans. This art form has become a valuable tool for water scientists who discern spatial and temporal patterns for everything from vegetation health and lake temperatures to rainfall intensity and ocean chemistry.

Ocean Pollution: Artist Jane Quon has brought attention to the detrimental effects of ships' dumping ballast water into marine ecosystems by creating a project whereby each component contributed to a cumulative field of aesthetic communication with the public. In doing so, she created a kind of evolving language that is available to people through the medium of art without their having to engage the rational mind. Her art communicates, beyond words and numbers, the juxtaposition between the patterns of natural harmony and ecological dysfunction.

Artists and scientists are uniquely positioned via their respective training and creativities to view the world in different, but complementary ways. Functional art is just one of the ways that they can collaborate on designs that are aesthetically pleasing, practically applied, and designed to emulate nature's patterns and rhythms. Artists have been described as a kind of sensing element for humankind because they are often the first to notice disruptions in nature's rhythms. If so, it may behoove water scientists to consult with artists during all phases of research.

STEAM 2017

BACK TO TABLE OF CONTENTS(/AUGUSTSTEAM2017CONTENTS.HTML)

The Commonality of Patterns

By West Marrin, *Ph.D.*

According to the STEM to STEAM website (http://stemtosteam.org), two of the movement's major objectives include transforming research policy such that art and design (A) are integral to science, technology, engineering, and mathematics (STEM) and influencing employers to hire artists and designers to drive innovation. Many significant breakthroughs in the arts, sciences, technology, and design fields have arisen, not from modifications of existing views, but from fundamentally different ways of perceiving the world through the senses or intellect. Artists and scientists are positioned via their respective training and creativity to view the world in different, but yet complementary, ways. STEAM's goal to more creatively address today's challenges will require effective communication as the theories, mathematics, and applications of technology or science find common ground with the images, sounds, and forms of art or design.

Although art and science were closely linked during the time of Galileo and Leonardo, modern trends have almost totally disconnected A (art/design) from the more analytical STEM pursuits. Distinguishing artistic images from rigorous mathematical or scientific descriptions of the world has resulted in less and less interaction between the two groups. Though the expansion of digital media and an international open-source movement could assist in encouraging interactions, a shared computer literacy alone is unlikely to bridge the professional chasm. Whereas similarities between art and science in perceiving and describing the world have been recognized, there are few formalized methods for utilizing those commonalities to enhance

STEAM.

Long-standing arguments as to whether artists can accurately portray the intricacies of scientific theories or whether scientists and engineers are able to recognize the expressive nuances and subtle messages of artistic works may be moot when it comes to STEAM. Physicist David Bohm believed that the value of art to a scientist is not the artist's statement, but rather a perception of the world that sidesteps entrenched thoughts or approaches.**[1]** Similarly, he considered the value of science and math to artists not as capturing theories in artistic works, but instead pondering technical understandings as a means of expanding perspectives on art and the world.

Communication

When considering communication among practitioners from different fields, words or symbols or numbers are often proposed as candidates for a common language, but they may not be the best choice. Spatial and temporal patterns might be more effective simply because they are fundamental to the natural world and have served evolutionarily as indicators of environmental threats or available resources for humans. People's aptitude for recognizing patterns applies to both spatial (e.g., shapes, geometries, relative positions) and temporal (e.g., rhythms, vibrations, cycles) phenomena. The recognition, interpretation, and projection of patterns probably underlie advanced human abilities such as language, music, art, and science.**[2]** Mark Mattson posits that these abilities, which he believes confer competitive advantages in a modern context, are derived from a human neocortex that detects and creates patterns in ever more abstract ways.

Inventor Ray Kurzweil noted that there are no images, maps, audio recordings, or videos stored in the brain, but rather sequences of patterns that are created and retrieved via a sophisticated mode of parallel processing.**[3]** Shapes, numbers, words, and even ideas are all stored as patterns, which themselves are composed of simpler patterns arranged hierarchically. This arrangement probably underlies people's efficiency in recognizing and projecting patterns, such that their thoughts are represented by patterns of interconnected neurons. By contrast, the brain's ability to assess logic and cause-and-effect is more limited, which is evident as people's incongruous ideas or actions.

The notion that patterns could represent a means of communication for scientists, engineers, mathematicians, artists, and designers is actually not a new one. So-called pattern languages have been applied to both technological and natural systems, while art and music have been described in terms of visual patterns and rhythms as a combination of elements that repeat in a predictable or unpredictable fashion. Whereas only certain branches of science specifically focus on patterns and rhythms in nature, the data from many scientific fields can be expressed in terms of cycles, frequencies, vibrations, sequences, and other descriptors of temporal patterns as well as shapes, distributions, geometries, structures, and similar descriptors of spatial patterns.

Regarded as the fundamental language of STEM, mathematics has been presented as rhythmic sounds and movements to teach otherwise abstract subjects such as arithmetic. Additionally, mathematicians themselves seek patterns in data to explain relationships that assist in describing and predicting natural phenomena.**[4,5]** Hierarchies of diverse patterns could be an interesting way to describe the world because humans originate from and embody many of the same physical patterns that they perceive (either consciously or unconsciously) as pleasing and ordered in the world and from which they infer meaning, causation, and familiarity.

Pattern Types

So, what commonalities are inherent in the geometries, cycles, symmetry, balance, and repeated patterns in nature that artists and musicians incorporate into their works and compositions and that scientists and engineers reveal in their theories and mathematics? And how might STEAM members actually communicate with each other using temporal or spatial patterns? A possibility was advanced by architect Christopher Alexander, who designed a pattern language specifically for collaborations among professionals with different backgrounds or people possessing limited knowledge of a particular topic.**[6]** Pattern languages are also popular among software developers because they permit people to discuss strategies and solutions without invoking programming jargon, which is often a barrier to sharing diverse ideas.

Listed below are a few examples of pattern categories and the rationale for their use.

***Archetypal Patterns*:** Among the most fundamental patterns are the Platonic solids, logarithmic spirals, and phi-based structures that are present in nature, music, and art. An inability to identify archetypal patterns in a mural, pyramid, seashell, or Mozart symphony does not preclude their recognition on more subtle levels. By contrast, some crystals and organisms display archetypal patterns that are easily recognized. An icosahedron is the Platonic solid identified during the 19th century as connecting many branches of mathematics, and physicist Garrett Lisi more recently used the 248 vertices, or intersection points, of an icosahedral-based pattern (E8 Lie geometry) to map the known and predicted particles of physics—although the math has yet to be resolved.

***Symmetrical Patterns*:** Symmetry is the property of an object such that changing its position relative to a viewer results in its appearing exactly the same (e.g., a spinning sphere or mirror images of a human face). Patterns with greater symmetry are more attractive to people, perhaps because symmetry is a perceived indicator of quality or because it permits the recognition of objects from different visual orientations. In either case, a human sensory bias for symmetry is evident in both nature and the arts. A desire to impose order on the world through projecting or creating patterns via art and design has been evident throughout human history.

***Fractal Patterns*:** Irregular or asymmetrical objects that appear randomly formed are actually not random from a mathematical perspective. The most familiar irregular objects are fractals, which display a very similar pattern over a wide range of scales. Although not a geometry that is easily identified by humans, it is the most common one in nature (e.g., clouds, waves, trees, mountains, rivers, coastlines). Interestingly, humans display a range of proficiencies in recognizing natural fractal patterns, perhaps because they are produced by complex nonlinear systems that are not easily discerned or comprehended. Nonetheless, the human brain can naively recognize and even strongly prefer certain types of fractal patterns without people being able to explain why.

***Network Patterns*:** Networks are probably the most difficult patterns to identify because their individual components and the interactions between them are not always obvious. Paradoxically, the brain itself functions as a complex network, as do many social, ecological, and technological systems. The dynamism of networks includes temporal patterns that, guided by spatial patterns, are responsible for the observed behavior of complex systems. Christopher Alexander identified his pattern communication in terms of a network whereby individual patterns are related to or dependent upon one another. Networks are evident in art and design as both abstract forms and images that highlight interconnections among human creations and nature.

Universality

In his book *The Self-Made Tapestry*, Philip Ball investigated the appearance and causes of patterns in nature and found that similar patterns within the physical, biological, and geological realms could be attributed to many different forces or mechanisms.**[7]** As such, the universality of patterns seems to transcend their respective causal mechanisms. Perhaps fractality, symmetry, and complexity simply represent different lenses through which we choose to perceive nature's patterns—and then to portray or utilize them in art and design. He posits that pattern seeking is hardwired into our brains, and the belief that nature's patterns were intelligently designed is a consequence of how humans create patterns (i.e., constructing symmetry) rather than how nature creates them (i.e., predominantly breaking symmetry). Ball further noted that similarities among pattern-forming systems serve to dissolve divisions among disciplines, thus permitting scientists, economists, engineers, and others to communicate in the same language.

Identifying a basic collection of patterns, the supporting components, and a few rules for structure could serve as an initial step toward developing a common STEAM language. While proposing protocols and syntax for communicating via patterns is beyond the scope of this brief article, a common language that could bypass the specialized jargon, symbolism, and styles of STEAM participants could enhance their collaboration. Perhaps the perceived beauty of a painting, a scientific theory, and a pristine landscape is related in a way that defies words, but not patterns.

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D.L. Marrin (nickname West) is an applied scientist in biogeochemistry, water resources and aquatic ecology. His clients include environmental consultants, public health agencies and R&D firms. He developed analytical and interpretive techniques to assess pollutant dynamics in aquifers and surface freshwaters and identified chemical markers to detect wastewater impacts on coastal marine ecosystems. He lectures on global water quality, local water footprints, hydromimicry and the water-energy-food nexus. His latest work is with artists and designers in developing collaborative tools to communicate science via spatial/temporal patterns and applying artistic perspectives to scientific research via functional art. West maintains a multi-faceted water forum (www.watersciences.org) and is a former adjunct professor at San Diego State University. He has a Ph.D. in water resources from the University of Arizona, as well as B.S and M.S. degrees in the biological and environmental sciences from the University of California.