Modeling Emergence: A Design Science Method for Whole Systems Thinking

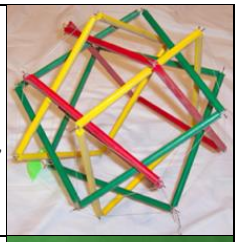
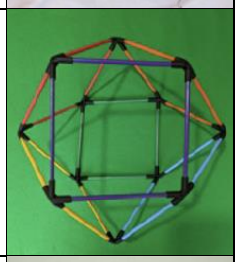
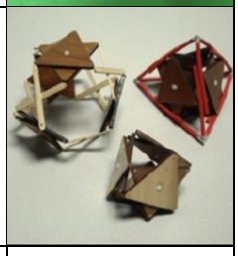
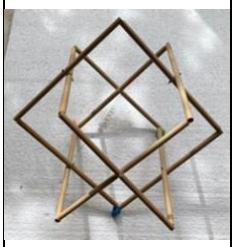
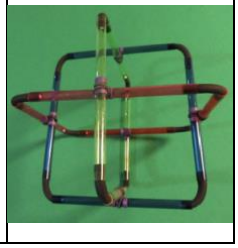
Together we, of whatever belief, history, or culture, must work together to create a common future -a future that respects the rights and aspirations of all people, values the spirit of learning, celebrates the values of beauty and truth, and cares for our planet's health. *F. David Peat, Certainty to Uncertainty*

Al Gore points out in his book, *Earth in the Balance; Ecology and the Human Spirit* (1992) that the critical planetary emergency facing us today is "Global Warming" and asked, "what can we do about it?" Design plays a crucial role in addressing climate change by shaping our built environment, influencing cultural behaviors, affecting policy decisions, and fostering resilience in life. We draw inspiration from Buckminster Fuller's approach to what he termed "Comprehensive Anticipatory Design Science" to solve such problems. By employing the teleological approach of whole systems modeling, we will introduce a novel class of "X-motilitY Systems" – geometric models designed not merely to mimic structural features, but to capture and to explore Nature's dynamic, self-generating behaviors. During the workshop session, we will discuss motions and forces in Nature with "X-motilitY" bio-inspired structural systems. These dynamic models combine the internal and external forces to demonstrate the transfer of energy within the structures themselves.

During the presentation, we underscore the intrinsic role of play in lifelong learning, and point out the importance of whole systems thinking. Constructivist education methods demonstrate the power of model-making for multisensory, self-directed, hands-on exploration. Embodied learning, or praxis, engages all the senses. In the model making process, participants will sense and experience how systems emulate the forces, motions and behaviors of Nature. The table to the right shows the progression of dynamic models from stability to motility. These models exhibit the following properties: tensile, adaptable, transformable and self-generated, energetic movement, exemplifying Nature's design principles.

Nature's structures are always seeking balance, they are never static. X-motilitY Systems demonstrate how geometric constraints are used to achieve torsional equilibrium, balancing the torque forces generated by the bending and twisting of diverse materials and/or thoughts on problem-solving. Flexible materials with different torsional properties are used as joints that bind the structure together, exhibiting how torque can be absorbed and released. This leads to motile behavior as the system transitions between different geometric configurations of transformational polyhedra. The movement of these materials illustrates how the behavior of whole systems emerges from the interplay of constraints dictated by their structural and material characteristics.

During the hands-on session, participants will construct the basic X-motilitY structure. They will be given a selection of materials to choose from to tailor the model's behavior for different applications. Various applications will be examined depending on weight bearing, weight sensitivity, jumping ability, agility and efficient use of materials. Each team of participants will have enough material to construct at least one basic X-motilitY structure. The last stage of the hands-on we'll encourage teams to combine their structures together to form more complex structures.

Stable and Tensile **Stable structures:** Fixed lengths, fixed areas, fixed directions **Tensile structures:** tension & compression, material constraints, efficient use of materials *Tensegrity:* Arthur Loeb Collection	
Transformable **Shape transformation:** Geometric constraints (includes twist), removing constraints (expansive, contractive, growth); unique symmetries at different stages *Jitterbug:* R.Buckminster Fuller	
Kinetic **Adaptable:** incremental, reversible deformable, deployable, mobile, rotation, translation, woven, linkage systems *Chiral Polyhedra:* Joseph D. Clinton	
Motility Structures **Motile**: based on torsional equilibrium with the ability to transform simple external forces into directed motion. *X-motilitY System:* by the authors *QR-code links to a video demonstration of X-motilitY Systems*	 

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