Table 1

Fichter, Lynn S., Pyle, E.J. and Whitmeyer, S.J, 2010 (in press), Strategies and Rubrics for Teaching Chaos and Complex Systems Theories as Elaborating, Self-Organizing, and Fractionating Evolutionary Systems

Universality Principles of Chaos Theory		
Model	**Representation**	**Principle**
Logistic System - X_{next}	Time series diagrams	1. Computational viewpoint 2. Positive and negative feedback 3. r values 4. Deterministic ≠ predictable
Bifurcation Diagram	Part One: Generating the bifurcation diagram	5. Bifurcation = change in behavior 6. Instability increases with ‘r’
	Part Two: Self-Similarity (Fractals): Zooming in on the bifurcation cascade	7. Self similarity
	Fractal geometry (more depth on self similarity)	8. There is no typical or average size of events or objects. 9. Non-whole number dimensions
	Part Three: Feigenbaum ratios	10. All complex systems accelerate their rate of change at the same rate
	Part Four: Attenuating bifurcation diagram	11. All changes are preceded by increasing instability
Sensitive Dependence	X_{next} time series diagrams at 4.0000001 compared with 4.0000002	12. Minuscule changes in ‘r’ can result in dramatic changes in behavior
Power Laws	Log-log graph	13. Small–low energy–events are very common but do very little work. Large–high energy–events are very rare but do most of the work.
Strange Attractors	Phase space	14. Chaos/complex systems have behaviors that may superficially appear random, but have recognizable large scale patterns.

<table>
<tr><th colspan="3">Principles of Elaborating Complex Evolutionary Systems</th></tr>
<tr><td colspan="2">Typical Elaborating Evolutionary Models</td><td rowspan="4">15. The general evolutionary algorithm—1) differentiate, 2) select, 3) amplify, 4) repeat—is an extremely efficient and effective method of natural selection.</td></tr>
<tr><td>WordEvolv</td><td>Computer calculated algorithm</td></tr>
<tr><td>John Muir Trail</td><td>Narrative description diagrams/charts</td></tr>
<tr><td>Tierra</td><td>Narrative description with diagrams/charts</td></tr>
<tr><th colspan="3">Principles of Self Organizing Complex Evolutionary Systems</th></tr>
<tr><td>Boids</td><td>MatFa’s Boids program (along with many other available programs)</td><td>16. Local Rules lead to Global Behavior, self organization arises spontaneously without design or purpose</td></tr>
<tr><td>Self-Organized Criticiality</td><td>Sand pile model</td><td rowspan="2">17. All natural open systems dissipating sufficient energy evolve–self-organize–to critical, sensitive dependent states which leads to avalanches of change that follow a power law distribution.</td></tr>
<tr><td>Cellular Automata</td><td>Life3000 program (along with many other available programs)</td></tr>
<tr><td>Bak-Sneppen Ecosystem</td><td>Bak-Sneppen computer driven algorithm</td><td>18. In a complex system everything is connected with everything else. Nothing exists in isolation from the rest, sitting in a protected niche, independent and self-sufficient.
19. In a complex system no one can be completely safe, with complete control over their fate. Everyone is an innocent victim since there is no way one can fully protect oneself in such a world.</td></tr>
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