

Fractals and Chaos in the English Classroom

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Overview

Rationale

Objectives

Strategies

Classroom Activities

Annotated Bibliography/Resources

Appendices-Standards

Overview

An English teacher taking a seminar on fractals and chaos seems random, but a closer look reveals an intersection of patterns between science and literature. Studying the science of chaos and its recursive figures of self-similarity is an interesting way into some of the literature read, discussed and written about in an accelerated twelfth grade English class.

Rationale

The purpose of this unit is to develop a way of reading, thinking and writing about the art and literature to be studied in a twelfth grade English class for gifted students. Whereas in the past, I have tried to use an overarching theme of narratology or storytelling, as a way to discourse on plays, novels, nonfiction and even poetry, this unit will take the stance that what seems illogical, nonsensical, noisy or random in literature are really the first steps at reorganizing one's thinking at a more complex level. The unit will accelerate the students' learning when they recognize the necessity of reorganizing their ways of thinking about literature. I have come to accept that the seniors I get in September are mostly comfortable and familiar with realistic, plot driven mimetic fiction imitate aspects of the sensible world. When high school seniors read Ralph Ellison's *Invisible Man* or Tom Stoppard's *Rosencrantz and Guildenstern Are Dead* for the first time, they are often most displeased that things "do not add up." They observe the actions and speeches of the characters in these stories to be without rhyme or reason, or to use a popular phrase, "random." These kinds of metafictional texts, literature that reveal the chaotic structure of the world through the chaos of their own narrative system, are the kinds of books that can change the way students read. This is what an accelerated English course that prepares students for the Advanced Placement exam in Literature and Composition is supposed to do.

I have in the past thought that the kind of students that came to my class were somehow hardwired linear thinkers that could not interpret metaphorically, or that they were right-brainers destined to be engineers and technicians who could not reorganize their thinking to make any meaning out of ambiguous texts. Then I began to read about a discipline of mathematics that since its emergence in the 1960's has reorganized and revolutionized thinking in not only scientific disciplines of geometry, meteorology, biology, but has led to a revisioning of information theory, literary analysis and philosophy as well. As part of a Pittsburgh Teachers Institute seminar on Fractals and Chaos, I have been thinking new ideas that are starting to make sense in familiar ways. I am making connections between Louise Rosenblatt's transactional theory of reading and chaos theory of mathematics that looked for and found order in seemingly random phenomena of weather. I have begun to think that science, literature and visual art are all parts of a larger cultural system of making sense of the world. Such a postmodern idea, that people compose the meaning of the things they read, see, and hear, reinterpret the events and phenomena of the universe as new data is accrued, and construct a reality from the noise, information and experience of the world is the "strange attractor" at the nexus of science and art.

The story of the making of the science of chaos, which James Gleick tells in his book Chaos, is really the telling of the discovery of another level of order to the wide ranging and often what seemed to be disordered world of natural phenomena. From Edward Lorenz' early computer modeling of weather patterns came the idea of a complex system that was so dependent on and sensitive to unrelated conditions that made it impossible to predict with any accuracy the future behavior of the weather. Yet Lorenz saw in the complex system of weather the same kind of order that existed in other systems that never reached a steady state, the same kind of complexity named "strange attractor" by Ruelle and Takens in their paper that proposed that just three independent motions would produce all of the possible turbulence in a fluid (Gleick 133). Lorenz' work moved more and more away from meteorology towards mathematical modeling and brought forth the concept of the "Butterfly Effect"; the idea that because of system's sensitive dependence to initial conditions, the weather in Pittsburgh could be affected by the flapping of a butterfly's wings in Mexico (Gleick 23). The Butterfly Effect would be more than a seminal moniker of chaos theory; it would also show itself as a visual image that occurred when Lorenz used early computer models in some of the first experimental ways to graph in three-dimensions a system of non-linear equations. Such a system of nonlinear equations is not solvable, yet like the oscillation of weather patterns or the population of animals in a certain biological system, Lorenz' graph started at a point in space and moved in regular orbits around a fixed point but never on the same curve. The butterfly wings or owl's mask that were traced by the graph became a visual emblem for the early explorers of chaos. (Gleick 29)

Fractals and scaling in science and art

The science of chaos was pushed further into the consciousness of geometric mathematicians, economists, and electrical engineers by Benoit Mandelbrot's description and naming of the self-similarity he found within nature. In 1975, he coined the word *fractal* (derived from the Latin adjective *fractus* and verb *frangere* meaning to break) to name the shapes, dimensions and geometry he had been seeing all his life (Gleick 98). Mandelbrot was interested in describing the complexity of existence in a world that was not round, with lightning that did not travel in a straight line, and coastlines that were rough not smooth. In a departure from Euclidian geometry that described lines, circles, pyramids in one, two and three dimensions, Mandelbrot jumped to a fractional dimension to describe complex forms. Mandelbrot defined fractals as forms that displayed self-similarity or similar appearance at any magnification (Taylor 118). Thus a small part of the structure would look like the whole. Using a computer in ways that mathematicians previously were unable to compute by hand, Mandelbrot claimed a fractal dimension, D , to stand for a fractal's degree of irregularity or brokenness, and theorized that the degree of irregularity in a fractal remains constant over different scales (Gleick 98).

In the most famous example of the fractality of nature, Mandelbrot asked the question "How long is the coast of Britain?" and answered that it depends on what scale is used to measure it. Measuring from the distance of an orbiting satellite using a "ruler" graduated in miles would yield an answer that is at best an approximation of the bumps, curves and straights that form England's familiar L shape. But, Mandelbrot wondered, what would be the distance if the coastline were measured on the ground using a yardstick? Certainly it would not be a straight line measurement, or a dimension of 1, Mandelbrot intuited, for at that scale one could change directions and angles to follow more closely the bumps, curves and straights of where the land meets the sea and reach a circumference that would be greater than the distance measured in miles. Mandelbrot saw that the distance that would result from a measurement in inches with a scale that could be laid against every pebble and root would again be greater than previous scales even though the amount and pattern of bumps, curves and straights would be the same. The dimension of such an irregular natural object is not well served by Euclidian constructs such as point, line and plane; it is neither one dimension (a line) nor two dimensions (a plane). Mandelbrot calculated the coast of Britain to be a *fractal* dimension of 1.25, somewhere *between* 1 and 2 dimensions (Pollard-Gott 234).

Snowflakes are other figures in nature that show self-similarity across various scales. If we look generally at a snowflake we may see six points, but

looking closer we see that each of those points has points. At the edges and boundaries between the phase changes from liquid to solid, the water molecules each form their own crystal structure that repeats on a smaller and smaller scale in exactly the same pattern that the snowflake has on whole. This self-similarity across scales is what Mandelbrot defined as the outstanding characteristic of the fractal geometry he invented to describe the irregular forms of nature.

Creating a mathematical snowflake can prove that a fractal dimension lies between a line (1) and a plane (2). Koch's curve or snowflake starts with an equilateral triangle. Divide one side of the triangle into three equal parts and remove the middle part. Replace it with two lines the same distance as the one just removed, with the point facing outward. Do this to all three sides of the triangle. Repeating this process to every line segment of the resulting figure and you have a fractal (Lanius). If a circle were circumscribed around the three points of the original triangle, all of the generations of the snowflake would still fit inside the circle (dimension <2), but the actual circumference of the snowflake would be greater than the circle (dimension >1).

Pollard-Gott asserts that another fractal structure is useful in identifying patterns of images in literature. This structure lies between a point (0 dimension) and a line (1 dimension) and is called a *dust*. The most famous dust is the Cantor set, created by taking a line of length 1, dividing it into thirds and creating a space where the middle third is dropped. Each new generation of the figure divides the resulting line segments and resulting spaces in the same way (self-similarity) with an infinitesimal number of generations producing a resulting dust of line segments. Pollard-Gott's analysis of Wallace Steven's poems identifies a style of repeated words sprinkled throughout the poem like "dust" (234)

Mandelbrot's identification of fractals in nature and in the irregular but self-similar patterns of geometric shapes like Koch's curve was important because of scaling. Scaling was the bridge that Mitchell Feigenbaum used to connect the various scientists and mathematicians that were recognizing patterns in random sets of data, seeing order in fields of disorder, regularity in chaos. Feigenbaum's theory of universality provided a standard, quantitative way of measuring different systems, which is useful because the universe is too big, too complicated to understand by the usual scientific method which involves trying to sample enough data from enough different situations and then put it all into the biggest machine money can buy to try to estimate what will happen next (Gleick 186). Universality showed that phenomena exhibiting scaling behavior are related by an exponent of fractal dimension. We can know everything about something by examining the smallest part of it.

Then, as I read Gleick's book and his interview with Feigenbaum, I began

to see that all this science connected with the world of art as well:

The only things that can ever be universal, in a sense, are scaling things...What artists have accomplished is realizing that there's only a small amount of stuff that's important and then seeing what it was...When you look at early stuff of Van Gogh there are zillions of details that are put into it, there's always an immense amount of information in his paintings. ...With Ruysdael and Turner, if you look at the way they construct complicated water, it is clearly done in an iterative way. There's some level of stuff, and then stuff painted on top of that, and then corrections to that. Turbulent fluids for those painters is always something with a scale idea to it. (186)

Intersection of science and culture

Can a mathematical theory have application and validity in a discipline other than math or science? Chaos theory and identification of fractal geometries in nature have changed science and the way scientists describe the world. N. Katherine Hayles says that the goal of language in science is for words to have one meaning; that science decries the appropriation of chaos terminology and concepts by cultural and literary analysis (18). Hayles makes the point, however, that both science and literature are neither above nor apart from culture, but are part of it and embedded within it. Science and literature both affect and are affected by culture. No doubt mathematicians' recognition, naming and solving systems with two or more factors acting independently of one another changed the larger culture's fundamental belief in order and the search for it (17), but Hayles questions if the science of chaos is the only source from which ideas like nonlinearity, scaling, and sensitive dependence on initial conditions have spread into the culture. She asks if language conveys ideas or constitutes them, and if scientific inquiry and analysis is culturally conditioned.

There is no avoiding the connotations that go with the word chaos, and maybe science purists today wish that the early thinkers in chaos theory had picked a different word to represent the field that they were creating. Lorenz, Smale, Mandelbrot were looking for a way to describe the complex behaviors of fluids, weather, of systems that had more than two independent forces. James Yorke, a mathematician struck a chord when his paper entitled "Period Three Implies Chaos" gave a name to the erratic behavior that physicists and mathematicians observed and tried to ignore as noise or bad science. Until they got the idea of disorder, Yorke thought, scientists and nonscientists would mislead themselves in looking for the grand scheme of periodicity (Gleick 68).

Western cultural attitudes that go along with the word "chaos" derive from its characterization as the negative void that must be conquered for creation to

occur. The Oxford English Dictionary first defines chaos as “any vast gulf or chasm, the nether abyss, empty space, the first state of the universe,” and secondly as the “formless void of primordial matter, the great deep or abyss out of which the cosmos of order of the universe was evolved.” Hesoid’s *Theogeny* was a genealogical account of the Greek gods that personified the beginning of all things as Chaos, the most ancient of the gods who preceded Earth and Heavens and Tartarus, the underworld. Hesoid’s account, like many other creation myths, from the Babylonian epic *Enuma Elish* to the Taoist *Zhuangzi*, imply chaos to be the savage foe that must be vanquished before order and civilization can begin (Hayles 2). Such a negative view of chaos may come from a binary bias of western logic: order is good; chaos is bad. Such a bias may obscure the thrust of chaos theory, that chaos may lead to order in self-organizing systems, or it may have deeper structures of order encoded within it (Hayles 3).

Here is a place where science meets postmodern culture, says William Paulson who defines literature as a self-organizing system with “the principle of constructing a pattern out of what interrupts patterns ... inherent in artistic communication” (44). Like the chaos pioneers in math and science who worked outside the mainstream in their fields, aesthetic thinkers, reading critics, and information theorists began to think differently about where the meaning of a text resides. Paulson says a modern sense of the word “literature” was born in an eighteenth century movement of dissension from the triumph of Cartesian-Newtonian reductionism when Diderot, writing in the *Encyclopedie* on “the Beautiful” argued that the source of beauty depends on the idea and the perception of relations (Paulson 40). Karl Phillip Morris extended this notion of beauty as a created being when he wrote in the 1780’s that a work of art is a totality that constitutes its own finality, with organic replacing imitative and complexity replacing simplicity as formal ideas (Paulson 42). Works of art were coming to be understood not as imitations of a prescribed form, but as a synthesis of ideas and forms organized into a new understanding. When Henry Poincare conjectured in 1903 that arbitrarily small uncertainties in the initial conditions of a system might lead to a wide variety in the outputs of the system, he could as well have been discussing literary texts as he was describing noise in a scientific experiment. Around 1960, Heinz von Foster and later Henri Atlan identified as a self-organizing system any organism that finds not only information but also noise in their environment and is capable of modifying their structure to make information out of the noise (Paulson 40). Von Foster and Atlan presaged cybernetics – information theory that posits that a system reorganizes itself to make sense or use of new information that previously may have been seen as noise and disregarded.

Paulson says Jurij Lotman makes the connection between science and literature in *The Structure of the Artistic Text* when Lotman conjectures that noise

within and outside a text can lead to new levels of organization and understanding not predictable nor under the authority of the writer (43). This was what Louise Rosenblatt made claim to in 1938 with her transactional theory of reading in the seminal text *Literature as Exploration*. Rosenblatt's work was then and is today a defense of the reader as a self-organizing system that makes meaning of a text in the process of reading it, rather than the author of a story, poem or text having sole ownership of what the words on a page mean. Paulson talks about literature as emergent in the same way. Unlike non-artistic communication that would ignore or discard noise that is outside the code of transmission, artistic texts are polysystemic, indicating by the transmission of information that is out of code or noisy, that another level or creation of a new code is needed. Literary texts are noisy, communicating a variety of information both recognizable and ambiguous. Ironically, says Paulson, literature and science are related parts of a system much larger than either, yet separated by the languages that have arisen to describe each (49).

The parallel between science and art is what gives hope for a world that can renew itself, reorganize itself, rather than entropy constantly running itself down to heat death as the Third Law of Thermodynamics predicts. Just as Feigenbaum's theory of universality used the scaling nature of chaotic systems to know everything about a system by learning just one small part of it, my students do not need to know a lot of everything to get the meaning intended in a complex text like a fractal poem or a metafictional novel. As Paul Stoicheff concludes in "The Chaos of Metafiction," we are the product of the narratives we tell. Introduction of chaos into our stories separates our plots and characters from meaning they may have had previously, but the world will seem chaotic and without order unless and until we reorganize our view as chaotic. It is all a jumble until we are inside and part of the chaos (95).

Objectives

This unit will be necessarily cross-disciplinary, including some science and math background information on fractals. Students will be able to explain what a fractal pattern is, define and give examples of self-similarity and scaling concepts and create a simple fractal geometry like Koch's snowflake. Through reading, discussion and writing, students will also be able to read and understand essential content of informational and narrative texts. The unit makes use of two novels and two plays and requires students to understand, analyze and compare and contrast the author's use of literary devices, figurative language and literary structures such as foreshadowing and flashbacks. Students will write portfolio worthy narrative pieces of their own including short stories and poems.

Strategies and Classroom Activities

To teach 12th grade gifted English students of the chaotic and fractal nature of art and literature will take more than just a 2 or 3-week unit. I imagine that introducing and examining examples of these concepts will need to occur over an entire year of the course. I expect that such a strand of chaos and fractality in literature would begin with an introduction of the concepts. I like to throw curveballs at my students and take them off their guard. I find that removing them from their familiar “Go ahead, teach me” stance is good for getting them to look at things in a new way. Asking them to read novels and poetry in ways other than “Who are the main characters and what is the conflict?” or “Identify the instances of onomatopoeia in this poem?” can throw them off their game enough to see other ways.

I would introduce the concepts of chaos and fractals with a series of images: tree branches, clouds, the Mandelbrot set, fern leaves, galaxies, tree bark and Jackson Pollock paintings. I would ask for reactions and responses to the images, then ask more specific questions such as what each of them has to do with the others, and what similarities do they find among them. Then by arranging a slide show of increasing magnification of one of the images (tree branches) and then another (galaxies) then a final series (Blue Poles: Number 11, 1952) I would ask the class to respond to the *self-similarity* they saw within each group of slides, and use the comments as an introduction to the concepts of fractals and chaos. I would really like to plan this introduction as a cross-disciplinary lesson with the Physics 2 teacher and have students investigate and research definitions and examples of each for presentation to one or both of the classes with the goal of defining as a group what chaos and fractals are. Assigned reading would include Taylor’s article “Order in Pollock’s Chaos,” and Lanius’ website on fractals.

This may take a few weeks for students to discover and formulate, which they could do while we read *Invisible Man* by Ralph Ellison. Here I would bring out the ideas of mimetic and metafictional texts, as well as the philosophy of postmodernism, which at its base explains that humans impose meaning on the chaos of their experiences. That the universe is random and chaotic may be a stretch for these students, but I want them to stretch, to open themselves to new ways of looking at what seems. Mimetic texts, according to Paul Stoicheff, are narratives that masquerade as a copy of the world. Realism is mimesis, where an author tries to recreate the sensations and experiences of a group of characters engaged in their lives which may seem to play out in ordered regularity. Metafictional texts, although they use the conventions of narrative, reveal how the “emergent” chaos of the text and of the world are one (94). Stoicheff says that for writers of metafiction such as Luis Borges, Victor Nabakov and Thomas Pynchon, “the world is a text that is read, and our interpretation of our world is a function of our reading of texts” (95). Thus, he argues that we are products of the

narratives we tell and read and introduction of chaos into our stories separates our plots and characters from meaning they may have had previously. He posits that once we organized our view of the world as chaotic that the world then becomes meaningful (95).

Such a metafictional reorganization, Judith Tabron and Timothy Spaulding argue, would cause readers of *Invisible Man* to see Ellison's novel not as a chaotic and inscrutable story of a young black man who lives in a hole illuminated by thousands of light bulbs, but as a metafiction that makes meaning of the characters and events of the unnamed narrator's world; our world. Tabron's chapter titled "Ellison, Technology and *Invisible Man*" makes the case that *Invisible Man*'s rude experiences, his grandfather's dying words and prophetic dreams, as well as the surreal events of the Liberty Paint Company, the Brotherhood and the chaos of the Harlem riots are the iterations of a fractal order working itself into a culture of invisibility. Tabron uses a black and white fractal figure (155) to represent the oscillation of identities that *Invisible Man* tries to fit into, but will never be seen as because his self is outside the set. "The novel gets it, but *Invisible Man* does not" (Tabron 94).

Spaulding also sees *Invisible Man* as metafiction, and the anonymous narrator as bebop jazz improviser who must recognize and try on the texts of his past before expressing his own identity:

Ultimately, the shift allows the narrator to interweave all of these musical languages into his own, seemingly chaotic, narration. What results is a sequence rooted in a bebop aesthetic – distorted and dissonant on the surface but melodic on a deeper level. The narrator's virtuosity lies in his ability to convert these disparate sources into his narrative improvisation. (493)

Ellison's sensibilities as a jazz musician show as the world of *Invisible Man* is a chaos of jazz characters: Jim Trueblood as the Blues storyteller/trickster who sells his story for \$100; Peter Wheatstraw as the signifying bluesman; and *Invisible Man*, who like a jazz musician that "woodsheds" or sequesters himself from public performances to develop his improvisational chops, goes underground to find his voice and transform the chaos into narrative form (Spaulding 499).

Students will be changed by reading *Invisible Man* as metafiction, and as Hayles says, may be unable to read any texts thereafter without seeing them as metafiction. I can at least hope that they will see literature to be communication crafted to maximize the positive role of noise (20).

Revisioning literature

Shakespeare's *Hamlet* has for centuries been read, performed and seen as an Elizabethan revenge tragedy. We could call it mimetic as Shakespeare crafted it from Scandanavian folk tales to mirror what happens to corrupt people who use their power to hold onto their position. The paradigm shift that occurred since Mandelbrot, Lorenz and others learned to describe the order in their chaotic data has since extended to literature, as "chaoticists" such as Hayles begin to re-see literature as emergent; that is, with qualities not included in or predicted from knowledge of the system in which they arose (44). Therefore, the noise within and outside a text like *Hamlet* can lead to new levels of organization and understanding not predictable nor under the authority of the writer Shakespeare (43), and a play like Tom Stoppard's *Rosencrantz and Guildenstern are Dead* can be understood through the lens of mathematical chaos theory as a metafiction of non-linear dynamical systems with a sensitive dependence on their initial conditions.

In this unit we will read both Shakespeare's *Hamlet* and Stoppard's *Rosencrantz and Guildenstern*. I think it will be fun and instructive to compare the two texts and to specifically watch Rosencrantz and Guildenstern, two minor characters in Shakespeare's *Hamlet*, hired by the King of Denmark to find out why their school buddy Prince Hamlet is acting so weird. Stoppard's play, like Shakespeare's, ends with the announcement by the British emissary that as per Denmark's orders, Rosencrantz and Guildenstern have been executed. This all seems totally random and illogical, as do the coin flips at the beginning of Stoppard's play that repeatedly turn up heads despite the 50/50 chance of a tails. However, what the stooges do not know and spend the whole play not being able to figure out, are that the initial conditions of the system they are in, Hamlet's ingenuity and drive to expose his uncle as his father's usurper, will kill them. Despite Claudius' best laid plan of shipping his suspecting nephew off to England with sealed orders (carried by Rosencrantz and Guildenstern) to execute Hamlet as a traitor, the resourceful Prince Hamlet discovers the message his friends carry, and without their knowledge, substitutes their names for his on the decree. Hamlet achieves a measure of revenge for the friendship they sold for a king's ransom. Chaos reigns in Denmark. Non-linear events, including Fortinbras' claim to the Danish crown, Ophelia's bow to her meddlesome father's will at the expense of her love for Hamlet, and Hamlet's mother Gertrude's own guilt by association with Claudius' incestuous rise to power determine the final outcome. Denmark is a rotten prison that collapses under the weight of its corruption and takes down all of the prisoners, guards, and wardens.

Examining literature in these fractal and chaotic ways may help some of the seniors I have in my English 4 CAS class who are budding engineers with a scientific and mathematical bent. Such an approach might be the bridge they need

to get them over their perceived chasm of understanding and on the road to enjoying literature.

Fractal Poetry

Fractals are recurring forms in a cumulative sequence that, when looked at from a distance, reveal themselves to be an intricate web. Viewing the whole of a fractal can be pleasing and beautiful, while examining the logical sequence of iterations reveals the structure underlying the form. All poems are patterned in some way, and some types of poetry are fractal in nature; sestinas and sonnets sound their music in a rhythmic form of beats and feet of meter, lines and stanzas of structure, rhymes of repeated sounds. When we read a poem, we sense its beauty and meaning by a look at the whole – hearing it read aloud, visualizing the imagery of its verse. Some kinds of poems when examined for the form the poet fit their ideas and emotions into show themselves to be even more beautiful when illuminated by the light of their structure. One literary scholar, Lucy Pollard-Gott, applied the mathematical techniques of fractal geometry to Wallace Stevens' poems and identified in the repetition of certain words a fractal dust pattern (248). Some mathematicians and even more literary scholars might look at such analysis as frivolous and a waste of words, but Pollard-Gott shows that an idea has taken hold, a paradigm has shifted and ways of thinking about the world, whether natural or constructed, have been changed irrevocably by chaos theorists.

This unit would look at the Cantor set, consider its mathematical paradoxes, and then look at Pollard-Gott's analysis of fractal dust in Wallace Stevens' poems. Students often say that analyzing poetry kills it, but the hope here is that they will have fun identifying the math in poetry. Similarly, Alice Fulton's article "Fractal Amplifications: Writing in Three Dimensions" develops a rationale or way of talking about the kind of poetry she or others have written. She compares the plane of poetry to the plane of a painting and the techniques that a painter might use to increase the dimensions of the space created on a canvas to the way a fractal poet breaks and composes forms and structures to increase the dimension of the poem. This way of talking about poems would tie back into the scientific research into Jackson Pollack as a fractal painter, or other painters mentioned by Feigenbaum as well (Gleick 186). A field trip to the Carnegie Museum of Art would be in order here to look closely at the recursive techniques that painters used.

The Threes of *Siddhartha*

Perhaps the last book we will read in the course is a short, simple but subterranean novel about Buddha. I like to finish the year with Hermann Hesse's novel *Siddhartha* because it echoes a theme I push since the first day of school –

seniors in high school need to become their own teachers. Although I have some things to teach my class, I believe the most important idea I can give them is to seek and learn from their own experiences. Even so, Hesse has crafted what be called a fractal novel, at least in form. Sobel outlines how *Siddhartha* is a novel on the levels of form, style and content is based on three. From the triple rhythm of the first sentence “In the shade of the house, in the sunshine on the river bank by the boats, in the shade of the willow wood and the fig tree, Siddhartha, the handsome Brahmin’s son, grew up with his friend Govinda” (Hesse 1) we can see the pattern of three. The book is divided into three sections of three chapters, each section reflecting one of each of the experiences of the mind, body and soul. These sections are divided by an interlude chapter with a river crossing. The river ultimately provides Siddhartha with the realization of the illusion of time and divisions. Like the imagery of a Wallace Stevens’ poem :

“...the flecked river/which kept flowing and never the same way
twice, flowing/Through many places, as if it stood still in one”
(Gleick 196),

like the fluid dynamics that chaos scientists studied, measured and ran thousands of computer calculations, science and art arrive at the same place that seems to hearken a constant, universal order to the jumble of everything.

I would have students read *Siddhartha* and then search for the pattern of threes in the form, content and style of the book, and more importantly, ask them to write about the purpose it served for Hesse and speculate, with evidence from the novel, what it means for the novel.

Macro and micro scaling

One way I imagine tying together these various plunges into chaos is a kind of bingo game that students play to learn definitions, practitioners, examples of and time periods for various movements in literature and art. The game is a way that students can make sense of what may seem like noise and random nouns. I would like to create an interactive learning tool that would help English 4 CAS students make sense of the drama, fiction and poetry that they have been studying in high school and see the connections between other art forms as well. I imagine a kind of game similar to the one created by Vince Thearle for his intro to art class at Pine-Richland High School. Students have a bingo card with a grid of images, titles, character names from different movements of literature and art. Each card is a different movement (Romanticism, Folktale, Classical, Feminism, Modernism, Realism, Postmodernism, Surrealism and others). Each card's vertical axis is labeled genre (poetry, fiction, drama, painting, music, sculpture/architecture) and horizontal axis with time periods. A caller for the game gives the coordinates for each ball s/he draws ("Twentieth Century poetry," "Nineteenth Century Drama" or "Classical architecture") and players mark their card on those coordinate points. On that point will be an image, title, or author

that player will need to know and be able to explain some things about when they claim "Bingo." One number would be called each day in class, and players would want to do some research on their spots. Over the course of a few weeks, someone should hit bingo, and then by explaining their card help to build a culture of understanding of literary history within the class. New games could be started every few weeks and as class builds familiarity with works, artists and movements, they may in fact be studied in depth within units covered over the course of the year (Thearle).

Chaoticists see that in the phase changes of increasingly complex systems can be found a kind of order that indicates a recurring pattern. It seems that both a macro and a micro view of any system is needed to perceive this pattern, scaling down or up. The Literature Movement Bingo game is a kind of macro view, where as the individual unit studies of a particular work and author is micro. A combination of the two over the course of a year or four of high school could help a student preparing for the AP English Literature and Composition exam. They would become familiar with specific works and authors, adept at the ways that the artists convey their meanings, and have more connections between the things they have seen, read, heard, written and talked about. We would be able to see the pattern that evolved as artistic works evolved from and alluded to previous works and movements.

Annotated Bibliography/Resources

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Fulton argues for the term "fractal poetry" to describe and emerging poetics for which she credits Emily Dickinson as a forebear and for which Fulton creates a nomenclature to describe the shifting linguistic densities which cause a three dimensional, "synaesthetic" effect. She suggests that "digression, interruption, fragmentation, and lack of continuity be regarded as formal functions rather than lapses into formlessness and that all shifts of rhythm be equally probable."

Gleick, James. *Chaos. Making a New Science*. New York: Penquin Books. 1987.

Gleick recounts and explains the development of the scientific discipline of chaos, beginning with Lorenz' "strange attractors," Mandelbrot's discovery and naming of fractal geometry, Feigenbaum's theory of scaling universality and recent applications in physics, biology, physiology, and thermodynamics.

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Hayle's introduction to this collection of essays explains the way that the mathematical and scientific disciplines of chaos intersect with the cultural realm. Hayle sees science as a "repository of tropes" to illuminate literary texts.

Lanius, Cynthia. "A Fractals Unit for Elementary and Middle School Students" 1996-2004. Rice University. 16 Dec. 05.
<<http://math.rice.edu/~lanius/frac/>>.

Paulson, William. "Literature, Complexity, Interdisciplinarity" *Chaos and Order*. ed N. Katherine Hayles. Chicago: The University of Chicago Press. 1991.

Essay argues that reading is a complex system in action; reader and text are in symbiotic relationship that requires reorganization at higher levels of complexity to make order out of what is initially construed as noise.

Pollard-Gott, Lucy. "Fractal Repetition Structures in the Poetry of Wallace Stevens" *Language and Style: An International Journal*. Vol 19, No. 3. Summer 1986. 244-249.

This article reviews the work of Mandelbrot as a basis for analyzing the self-similar pattern of repetition in a number of Wallace Stevens poems.

Rosenblatt, Louise. *Literature as Exploration*. Fourth Edition. New York: Modern Language Association, 1976.

In one of the most important documents about the practice of teaching literature, Rosenblatt argues that the literary experience – what some have called response to literature – is a performance, a transaction between reader and text in which both are modified during and long after the reading.

Sobel, J. "Form, Style, and Content in *Siddhartha*." *Hermann Hesse Page*. 04 April 2006. University of California Santa Barbara. 28 April 1997.
<<http://www.gss.ucsb.edu/projects/hesse/works/jensid.html>>.

This article analyzes Hesse's use of a self-similar pattern of construction for the novel based on the number three.

Spaulding, A. Timothy. "Embracing Chaos in Narrative Form: The Bebop Aesthetic in Ralph Ellison's 'Invisible Man.'" *Callaloo* 27.2 (2004): 481-501. MasterFILE Premier. Power Library. Carrick High School, Pittsburgh, PA. 14 Feb 06
<www.powerlibrary.org/interface/POWER.asp?ID=PL1749>.

The task of the author of this essay is to examine the book "Invisible Man," Ralph

Ellison through the cultural and aesthetic framework of bebop, the form of jazz that achieved the height of its popularity between the years 1945-1950, the time during which Ralph Ellison wrote the novel.

Stoicheff, Peter. "The Chaos of Metafiction." *Chaos and Order*. ed N. Katherine Hayles. Chicago: The University of Chicago Press 1991.

This essay asserts the characteristics of contemporary fiction that are postmodern and argues that more than just metaphorically; the qualities of nonlinearity, self-reflexivity, irreversibility and self-organization exist in metafiction texts that reveal the world's constructed nature.

Tabron, Judith. *Postcolonial Literature from Three Continents: Tutuola, H. D., Ellison and White*. New York: Peter Lang. 2003.

The chapter titled "Ellison, Technology and *Invisible Man*" asserts that the protagonist of Ellison's novel is a subservient object that oscillates between his attempt at the subject position of white men and the object position of women and black, which he finds uncomfortably similar. Tabron likens *Invisible Man*'s predicament to a fractal figure.

Taylor, Richard. "Order in Pollock's Chaos." *Scientific American*. December 2002. Vol. 287 Issue 6. p116-122. MasterFILE Premier. EBSCOhost. Carrick High School, Pittsburgh, PA. 14 February 2006
<www.ehost@epnet.com>.

Analyzes the appeal of the paintings of Jackson Pollock using physics and computers and the discovery that Pollock was painting fractals.

Thearle, Vincent. "Re: Literary History Bingo." Email to the author. 7 March 2006.

Thearle explains the art history bingo game he created and uses in his high school Intro to Art class. The game is a survey of visual art in four different time periods (Prehistoric to Baroque; Rococo to Post Impressionism; Art Nouveau to Regionalism; Color Field to Contemporary). Images of works from each time period are randomly arranged on different game cards that are distributed to students. The teacher calls the game by flashing images onto a screen and lecturing on the artist and work. Students keep notes so that they can identify the artist and/or title of the work if they get Bingo on their card. Over the course of a school year, over 100 images are reviewed.

Student Reading List

Ellison, Ralph. *Invisible Man*. New York: Vintage Books, 1989.
Novel of a search for identity by a young black man in 1930's Alabama and New York. Ellison uses historical settings and chaotic events to reveal patterns in a

coming of age story appropriate for anyone who must negotiate petty power mongers.

Hesse, Hermann. *Siddhartha*. New York: New Directions Publishing Company, 1951.

This short novel uses the historical character of the founder of Buddhism, Siddhartha Gotama to tell a story of enlightenment with a theme of the need to be one's own teacher.

Lanius, Cynthia. "A Fractals Unit for Elementary and Middle School Students" 1996-2004. Rice University. 16 Dec. 05.

<http://math.rice.edu/~lanius/frac/>.

An introductory lesson to the nature of fractals with exercises that can be done on paper or on a computer.

Shakespeare, William. *The Tragedy of Hamlet, Prince of Denmark*. Ed. Louis Wright and Virginia LaMar. New York: Pocket Books, 1959.

This version of the revenge tragedy is a collation of Quarto II and the First Folio of the play. This edition contains notes about the meanings of words, essential information about Shakespeare and his stage, and illustrations from the Folger Shakespeare Library.

Sobel, J. "Form, Style, and Content in *Siddhartha*." *Hermann Hesse Page*. 04 April 2006. University of California Santa Barbara. 28 April 1997.

<http://www.gss.ucsb.edu/projects/hesse/works/jensid.html>.

This article analyzes Hesse's use of a self-similar pattern of construction for the novel based on the number three.

Stoppard, Tom. *Rosencrantz and Guildenstern are Dead*. New York: Grove Press, Inc., 1967.

Stoppard's play takes two minor characters from Shakespeare's *Hamlet*, and by making them the oblivious protagonists in a chaotic world that they don't understand, allows the audience to see the workings of a world that has no order, even if the inhabitants of that world can't perceive it.

Taylor, Richard. "Order in Pollock's Chaos." *Scientific American*. Vol. 287 no. 6. December 2002.

This article analyzes the appeal of the paintings of Jackson Pollock using physics, and includes a brief history of chaos theory and fractals. The author's research using computer analysis discovers that Pollack was painting fractals

Materials for Classroom Use

Der-Hovanessian, Diana. "Fractals." *American Scholar* 58.3 (1989) 382.
MasterFILE Premier. Power Library. Carrick High School, Pittsburgh,
PA. 14 Feb 06
<www.powerlibrary.org/interface/POWER.asp?ID=PL1749>..
Presents the poem "Fractals," by Diana Der-Hovanessian.

Gleick, James. *Chaos. Making a New Science*. New York: Penguin Books.
1987.

Gleick recounts and explains the development of the scientific discipline of chaos, beginning with Lorenz' "strange attractors," Mandelbrot's discovery and naming of fractal geometry, Feigenbaum's theory of scaling universality and recent applications in physics, biology, physiology, and thermodynamics

Lanius, Cynthia. "A Fractals Unit for Elementary and Middle School Students" 1996-2004. Rice University. 16 Dec. 05. <<http://math.rice.edu/~lanus/frac/>>.
An introductory lesson to the nature of fractal with exercises that can be done on paper or on a computer.

Pollard-Gott, Lucy. "Fractal Repetition Structures in the Poetry of Wallace Stevens" *Language and Style: An International Journal*. Vol 19, No. 3. Summer 1986. 244-249.

This article reviews the work of Mandelbrot as a basis for analyzing the self-similar pattern of repetition in a number of Wallace Stevens poems.

Pollock, Jackson. *Blue Poles: Number 11, 1952*. 2003. National Gallery of Victoria. 29 May 2006. <<http://www.ngv.vic.gov.au/pollock/>>.
On loan to celebrate the 20th anniversary of the National Gallery of Australia, Pollock's abstract expressionist painting done in his drip style set records for its purchase price at the time of its acquisition by the Australian National Gallery in 1973. This site contains images of the painting as well as biographical and critical information about Pollock and *Blue Poles*.

Siqueria, Rodrigo. "The Cantor Dust – Fractal Poetry" 4 March 2006.
<http://www.insite.com.br/rodrigo/misc/fractal/fractal_poetry.html>.
Presents a poem with words and letters substituted for Cantor set diagram.

Appendix-Content Standards

Pennsylvania Department of Education Academic Standards for Reading, Writing, Speaking and Listening; Arts and Humanities; Mathematics; Science and Technology

1.1.11. Learning to Read Independently

- C. Use knowledge of root words and words from literary works to recognize and understand the meaning of new words during reading. Use these words accurately in speaking and writing.

1.2.11. Reading Critically in All Content Areas

- A. Read and understand essential content of informational texts and documents in all academic areas.
- Evaluate text organization and content to determine the author's purpose and effectiveness according to the author's theses, accuracy, thoroughness, logic and reasoning.

1.3.11. Reading, Analyzing and Interpreting Literature

- C. Analyze the effectiveness, in terms of literary quality, of the author's use of literary devices.
- Sound techniques (e.g., rhyme, rhythm, meter, alliteration).
 - Figurative language (e.g., personification, simile, metaphor, hyperbole, irony, satire).
 - Literary structures (e.g., foreshadowing, flashbacks, progressive and digressive time).

1.4.11. Types of Writing

- A. Write short stories, poems and plays.
- Utilize dialogue.
- C. Write persuasive pieces.
- Include a clearly stated position or opinion.
 - Include convincing, elaborated and properly cited evidence.
 - Develop reader interest.
 - Anticipate and counter reader concerns and arguments.
 - Include a variety of methods to advance the argument or position.

1.5.11. Quality of Writing

- E. Revise writing to improve style, word choice, sentence variety and subtlety of meaning after rethinking how questions of purpose, audience and genre have been addressed.

1.6.11 Speaking and Listening

- C. Speak using skills appropriate to formal speech situations.
- Use a variety of sentence structures to add interest to a presentation.
 - Pace the presentation according to audience and purpose.
 - Adjust stress, volume and inflection to provide emphasis to ideas or to influence the audience.

1.8.11 Research

- A. Select and refine a topic for research.
- B. Locate information using appropriate sources and strategies.
 - Determine valid resources for researching the topic, including primary and secondary sources.
 - Evaluate the importance and quality of the sources.
 - Select sources appropriate to the breadth and depth of the research (e.g., dictionaries, thesauruses, other reference materials, interviews, observations, computer databases).
 - Use tables of contents, indices, key words, cross-references and appendices.
 - Use traditional and electronic search tools.
- C. Organize, summarize and present the main ideas from research.
 - Take notes relevant to the research topic.
 - Develop a thesis statement based on research.
 - Anticipate readers' problems or misunderstandings.
 - Give precise, formal credit for others' ideas, images or information using a standard method of documentation.
 - Use formatting techniques (e.g., headings, graphics) to aid reader understanding.

9.4.12 Aesthetic Response Arts and Humanities

- D. Analyze and interpret a philosophical position identified in works in the arts and humanities.

3.1.12 Unifying Themes Science and Technology

- A. Assess and apply patterns in science and technology.
 - Assess and apply recurring patterns in natural and technological systems.
 - Compare and contrast structure and function relationships as they relate to patterns.
 - Assess patterns in nature using mathematical formulas.

- D. Analyze scale as a way of relating concepts and ideas to one another by some measure.
 - Compare and contrast various forms of dimensional analysis.
 - Assess the use of several units of measurement to the same problem.

2.9.11 Geometry

J. Analyze figures in terms of the kinds of symmetries they have.

2.11.11 Concepts of Calculus

A. Graph and interpret rates of growth/decay.