Introducing Chaos (Theory) into Science and Engineering: Effects of Rhetorical Strategies on Scientific Readers

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Introductions in scientific journal articles invite the community to read, accept, and build on new ideas. Often they open with standard moves that bid readers to attend to new findings that fill a serious gap in the literature on an important topic, thus connecting shared communal ideas and new ideas. How do these moves apply to "revolutionary" disciplines that lack a shared literature? Do introductory moves influence scientists' reading strategies? In a two-stage study, we analyzed introductions of four articles on chaos theory and then asked 12 scientists to think aloud while reading them. To investigate effects of disciplinary maturity, we chose two recent and two early articles. The early "revolutionary" articles differed strikingly from the more conventional recent articles in space devoted to old versus new information, use of citations and equations, and the nature of opening appeal. Scientific readers reacted differently to the recent and early articles, commenting more on new information in the recent articles. Across articles, however, they commented more on shared information than on new ideas. These results underscore the importance of connecting new ideas to the literature even when using unusual techniques to introduce radically new ideas.

Introducing Chaos (Theory) into Science and Engineering

Effects of Rhetorical Strategies on Scientific Readers

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In their recent book on the impact of print technology on academic communities, Kaufer and Carley (1993) described a paradox in the accumulation of scientific knowledge. Science depends on a steady supply of new ideas. Therefore, to foster scientific knowledge, to influence the course of future research, and, not incidentally, to advance their own careers, scientists work to generate and promote new

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ideas. However, because new ideas can be understood only in relation to assimilated disciplinary knowledge, the most influential new ideas may be those that rely on the most old ones. If too many new ideas are in circulation, a discipline cannot build up enough old, shared ideas to supply the context against which a new idea can be recognized as relevant, interesting, and important.

To regulate the dissemination of new ideas, scientific disciplines have developed a set of practices such as peer review, replication, and statistical confidence criteria, the primary purpose of which is to filter out ill-conceived or badly done work. Those disciplinary practices may also, however, retard the appearance of very new ideas. In the review process, the scales are weighted in favor of ideas and approaches that are not too new. Because reviewers judge new work in relation to their current beliefs and interests, radically new ideas may be dismissed as tangential or ungrounded. Myers (1985) has argued that the essentially conservative nature of the research funding process is warranted because funding helps to define a field, conferring legitimacy on approaches with implications beyond any specific project, changing careers and institutions, and diverting resources. These forces make publishing promising but radical new ideas difficult.

Similar conservative forces are at work even after projects are funded and journal articles appear in print. Although scientists must read widely to build up shared knowledge, they naturally have practical limitations on their time and attention. Keeping up with science can compete with doing science. Faced with a rapid proliferation of journals published at ever-shorter intervals, scientists adopt rigorous selection strategies to cull a small number of articles that they will actually read, choosing most often those that apply most directly to their current work, and reading only a small proportion of articles completely (Bazerman, 1988; Pinelli, Cordle, & Vondran, 1984).

Under these conditions, how can scientific writers persuade others to look at, work through, and believe their new ideas, let alone to become excited enough about them to adopt or build on them? Over the last 10 years, some rhetoricians of science have attempted to answer this question by examining the rhetorical strategies exhibited

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in scientific texts, others by observing how scientists write and revise their texts. These studies suggest that scientists typically introduce new ideas by strongly signaling their membership in an established community, by explicitly linking their current work to that community's most highly valued beliefs and interests, using the familiar given/new information paradigm. As scientists write, they devote considerable effort to deciding which articles to cite and how to phrase their descriptions of previous work in order to capitalize on the rhetorical force of connecting their work to a shared communal discourse (Blakeslee, 1993; Law & Williams, 1982; Myers, 1985).

The effort to demonstrate membership in a particular scientific community goes beyond choices about terminology and citations; it involves presenting disciplinary knowledge in such a way that it warrants the new work. One such strategy, identified by Swales (Swales, 1984, 1990; Swales & Najjar, 1987), is a series of rhetorical moves in the introduction sections of academic journal articles. Although Swales (1990) has somewhat modified his definition of these moves, we follow the original (1984) formulation with the following four moves:[1]

1. Move 1) announcing the topic and demonstrating its interest for a community
2. Move 2) reviewing previous research relating to the topic
3. Move 3) pointing to a significant gap in the previous work
4. Move 4) presenting the goal of the new work as filling the gap

Although these moves had not been spelled out in style guidelines, Swales found this pattern was quite frequent in the 158 articles he examined across a variety of academic disciplines. Such frequent adherence to the moves is likely to have arisen through the pressures of genre formation and imitation of published examples. However, it also indicates that this strategy is at least tacitly perceived as effective for introducing new ideas.

Although the four introductory moves may seem a straightforward and even formulaic way to situate new work within a familiar context, Paul (1991) has argued that they in fact allow writers to shape and revise that context, making the context fit the new ideas rather than simply fitting the new ideas to the context. This process requires considerable rhetorical skill. The review of previous work in the first and second moves serves to interpret and instruct as well as to remind; writers draw selectively on published work to create a suitable history for their project. The review must strike knowledgeable readers as fair; it must characterize the goals and status of the established work accurately. But it must also promote some aspect of the previous work that will be central in the new work. The uncovering of this gap also requires skill. Writers must identify their contribution with previous work while critiquing its quality or comprehensiveness strongly enough that readers will believe the gap is worth filling.

The finding that many scientists use a fairly conventional set of introductory moves raises two sets of questions that we address in our study: (a) If introductory moves depend heavily on connecting new ideas to familiar and established work, how can scientists ever introduce radically new ideas for which no previous literature is available? and (2) Are the introductory moves merely a stylistic convention or do they influence readers' reactions to new or unfamiliar ideas?

SEEKING ORDER OUT OF CHAOS THEORY

To answer these questions, we use the emergence of chaos theory as a disciplinary specialty to compare the introductory strategies used in early articles (1975 and 1978), when chaos theory was considered radically new and when little relevant research was available, to strategies used in more recent articles (1989 and 1990), after a considerable body of work had appeared. Thus, we examine the revolution and the evolution of chaos theory as it is reflected in a collection of disciplinary texts.

The study of chaos began as a narrowly mathematical concern. Rather than portraying the world as a collection of orderly, linear systems, chaos theory constructs a world composed primarily of chaotic or nonlinear dynamic systems. In the 1960s, chaos was first recognized in physical systems. Its implications for a variety of scientific and technical areas became quickly apparent. Over the past 20 years, chaos theory has begun to account for problems that were previously discounted as unmanageable "noise" in contemporary scientific theories, such as turbulence in liquids and gases, fluctuations in animal populations, patterns in the spread of diseases, and irregularities in heartbeats. Given the broad potential applications of chaos theory and its distance from the mainstream scientific outlook, chaos scientists have continually had to situate their work for a diverse and expanding readership. The challenge was particularly difficult in the early days, when chaos was completely unproven as a productive scientific approach. Therefore, the emergence of chaos theory offers a productive site for investigating the type and effect of rhetorical strategies used in revolutionary work.

HOW INTRODUCTORY MOVES MAY REFLECT DISCIPLINARY STATUS

In the first part of this study, we consider the applicability of the conventional introductory moves for ideas that are very new. Little is known about what kinds of introductory moves are used to introduce radically new ideas, how writers find an audience for science without an obvious past, or how strategies change as a new approach gains acceptance (Miller, 1992; Keith & Zagacki, 1992). Most journal articles are written within what Kuhn (1970) has called "normal science"—the working out of puzzles within the current paradigm of a scientific discipline. Achieving the necessary Janus-like stance between old and new work is relatively easy at these times. In fact, Prelli (1989) has concluded that, given the like training of members of a specialized field, the rhetorical adaptations used for writing most journal articles are "relatively predictable" (p. 112). However, when no obviously relevant community exists, such as when scientists wish to advance radically new ideas or cut across disciplinary boundaries, no common literature may exist to use as a legitimating context for the new work. How then do scientists draw in readers and convince them of the importance of their work?

Given the emphasis on establishing community membership, we might expect scientists touting "revolutionary" work to take a conservative approach. They might make very new ideas seem unthreatening by following conventions and appealing to common ground as much as possible. This approach was the choice of the two biologists in Myers's (1985) study. They worked hard to establish their standing in a field new to them by citing as much relevant research as possible and attempting to adopt the language of that field. Other studies have also found that migrants to another field often try to sound like insiders (Blakeslee, 1993; Law & Williams, 1982).

Alternatively, scientists may just break from the pattern—do something completely different—in an attempt to capitalize on the scientific loci of progress and discovery. For example, according to

Halloran (1984), Watson and Crick, in their famous double helix article, deliberately adopted a breezy style that flouted the impersonal conventions of scientific writing. Similarly, when critiquing the mainstream approach to evolutionary biology, Stephen Jay Gould flouted conventions for scientific style (Gragson & Selzer, 1993).

The strategies that authors adopt in revolutionary situations may not be an either/or proposition between conservatism and brashness. In her recent discussion of *kairos*, Miller (1992) has argued that the "gap" between old and new is constructed not only by the author's style but also by the constraints of the time period in which the article is written. Therefore, a bold approach may be appropriate for one "revolutionary" situation but not for another. Unfortunately, none of the studies we have cited (and here we unabashedly dig our own gap) focused specifically on introductory moves, and none have compared revolutionary articles to later articles to see how introductory strategies develop from the point when an approach is launched to the point when it gains a stable place in the literature.

We begin to address these questions with a close rhetorical analysis of the introductions of four scientific journal articles on chaos theory, two early and two more recent articles. In particular, we use the moves identified by Swales as a standard for conventional practice. We contrast the moves in the recent articles with those made in the early "revolutionary" articles to determine how they employ the given/new information paradigm. In addition, we look at other differences in the early and more recent articles, such as the use of equations and citations.

HOW INTRODUCTORY MOVES MAY AFFECT READERS

In the second part of this study, we investigate how these introductory strategies affect readers. This question has been studied only indirectly. Some features of introductions have been associated with the success of an article in attracting attention from readers. For example, Swales's (1984) first and second moves are common places to find citations of previous work. Citations were also central factors in Kaufer and Carley's (1993) model for predicting the "reach" of scholarly journal articles, as measured by the number of times they were cited in subsequent articles. Although Kaufer and Carley's model underscores the importance of tying new work to the best possible old work, they did not distinguish citations in the introduction from those in the article as a whole. The skill with which citations are presented—their setting within particular moves, for example—may be crucial, but gauging these effects requires both deeper textual analysis and direct observations of readers.

Few studies have been conducted of scientists reading and evaluating articles in their professional literature, and none that we are aware of have focused on how scientists read introductions. In surveys and interviews, scientists report reading introductions in order to decide what *not* to read or when to stop reading. To merit close reading, an article must seem relevant and interesting, judgments that scientists often make on the basis of the title and authors, as well as the most general sections of the text, including the introduction (Bazerman, 1988; Dillon, Richardson, & McKnight, 1989; Pinelli, Cordle, & Vondran, 1984). Still, little is known about whether specific rhetorical strategies can hook skeptical scientists into continuing reading. The few direct observational studies of scientists' reading processes have not focused specifically on rhetorical strategies. Wyatt, Pressley, El-Dinary, Stein, Evans, and Brown (1993) cataloged a large number of comprehension and evaluation strategies used by social scientists but did not associate those strategies with particular textual features. In a study of biologists reading an argumentative article on evolutionary theory by Stephen Jay Gould and R. C. Lewontin, Charney (1993) found that readers did respond to specific features of the text, such as the examples. However, because Gould and Lewontin deliberately employed an array of unusual rhetorical devices, it is difficult to draw conclusions about the effect of more standard moves in research articles.

What these studies have not investigated is the effect of introductory moves on scientists' judgments of a journal article and on their reading processes. Do rhetorical strategies influence the effort scientists devote to analyzing the text? Does the quality of the moves—their explicitness or clarity—influence readers' evaluations of the text? In this study, we begin to address these questions by combining textual analysis of the introductions of four scientific journal articles with observations of the reactions of 12 scientific readers. By tracking the readers' reactions at each rhetorical move, we investigate how textual features influence interest and attention.

RHETORICAL ANALYSIS OF INTRODUCTIONS

Selection of Articles

In order to look for changes in rhetorical strategies as chaos theory developed, we identified two prominent scientists whose work was important in the early years and who are still involved in current research: Mitchell J. Feigenbaum, a physicist who formulated a universal quantitative measure for chaos and developed a theory to explain it; and James A. Yorke, a mathematician who is credited with categorizing a set of phenomena and naming it chaos. Both scientists were identified as important early players in Gleick's (1987) influential popularization of the emergence of chaos. Both have also published extensively throughout the past 20 years.

In a separate study, Paul (1991) analyzed the introductions of 12 articles by Feigenbaum and Yorke, spanning the period 1975 to 1990. Of these, we selected an early and a later publication by each scientist, matching the dates and type of journal as closely as possible. Our analyses focus on the introductions of the following articles. Feigenbaum's early (1978) article, referred to here as "Early-F," which introduces his universal quantitative measures for chaos, is arguably one of the most important early papers on chaos theory. Yorke's early article (Li & Yorke, 1975), referred to here as "Early-Y," is also important as one of the first attempts to define the basic features of chaos. The later articles of Feigenbaum, Procaccia, and Tél (1989) and Ding, Grebogi, Ott, and Yorke (1990)—to be referred to here as "Later-F" and "Later-Y," respectively—were the most recent available from the same prestigious journal, *Physical Review A*, at the time our study was conducted.

The collaborative nature of scientific writing raises the issue of authorship. Although Feigenbaum is listed as the first author of both articles, Yorke is not. Yorke's coauthor for the early article was T. Y. Li, a student who, by the time of publication, was affiliated with a different university. Yorke's coauthors for the recent article are affiliated with him at the University of Maryland, though not all in the same laboratory. In her analysis of the 12 article introductions, Paul (1991) selected only articles written by Yorke in collaboration with this team and those by Feigenbaum in collaboration with coauthors of his later study. Given the well-known indeterminacies of authorship in research groups, we are not claiming that these styles are specific to Feigenbaum and Yorke as individuals, but rather to the research groups that they regularly participate in, designated as "F" and "Y," respectively. The similarities Paul found in style and structure within the early and later articles for each group and the contrasts across groups encourage us that these groupings are plausible.

Conformity to Conventional Moves

Our goal was to explore how chaos theorists have attempted to motivate other scientists to read their work: whether they have employed conventional introductory moves and whether these strategies were different in the early days of chaos, when little published research could be cited. We focus on introductions because they act both historically and rhetorically as the area scientists use for positioning their work within current scientific discourse. Using Swales's (1984) categories of rhetorical moves, we found systematic differences in the introductions of early and later articles concerning how the authors handled the given/new information paradigm. As we will see, in the early introductions, the authors used different approaches and spent more time creating "old"—or background—information before they discussed their new projects, whereas disciplinary maturity has allowed the authors in more recent introductions to use community "shorthand" to move more quickly through the old information to their own new projects. We argue, therefore, that the traditional approach to opening moves is not as useful for radically new ideas.

Later Articles: Making Conventional Moves

The analysis of the introductions of later articles revealed surprisingly close adherence to the four moves that Swales (1984) described, but not equally clear execution by the two authors. (See Appendices A and B for annotated sentence-by-sentence summaries of these introductions.) Both introductions open with classic Move 1 claims of interest in their topics, supported with citation-laden lists of problem areas to which chaos has been applied (Later-F, sentences [S] 1-2; Later-Y, S1). In Later-F, the interest is termed "explosive." Next, both introductions insert an early general purpose statement (Move 4a), presenting their research questions in general terms. Move 4a may be a standard variation in these journals; it occurs in all four articles examined here (Later-F, S3-4; Later-Y, S2-6; Early-F, S7-9; Early-Y, S13).

Although this additional move seems at first a significant deviation from the Swales (1984) pattern, Swales (1990) noted recursive moves in his in-depth study. According to his research, recursion, or cyclicity, seems to be used if the field is viewed as branching, although most of his examples focused on the cyclicity of Moves 1 and 2. Paul (1991) found Move 4a in half of the articles in her extended study.

The next move in both introductions is a review of previous research (Move 2), in both cases showing that researchers have been successful at handling one kind of system or process. In both cases, the gap (Move 3) is formed by noting the neglect of another related kind of system or process. In Later-Y, previous researchers had studied the effects of chaotic scattering through abrupt bifurcation but not through saddle-centered bifurcation (S20-22). In Later-F, Move 2 discusses equimeasure partitions that are easily calculated, and then Move 3 discusses nonequimeasure partitions that are difficult to calculate (S22-23). However, Later-F's gap is implicit, and therefore, somewhat unclear. The gap is also obscured by a proliferation of contrasting terms (borderline of chaos vs. chaotic regime; regular vs. incomplete trees). Both introductions end with a more specific purpose statement (Move 4b) that not only introduces more original material but also provides a section-by-section preview. The introductions of these articles clearly follow the Swales (1984) moves, displaying a standard approach to the given/new information paradigm. Thus, they provide a baseline for comparison with the introductions of the early articles.

Early Articles: Moves of Their Own

The introductions of early articles depart in some important ways from the conventional moves. (See Appendices C and D.) Although the introductions of these articles must generate interest and motivate potential colleagues to read, they use other means. Because these strategies are less common and because the authors we examined differed in the degree of their departure from the moves discovered by Swales (1984), we will describe the early articles in somewhat more detail.

The new opening tactic adopted in the introductions of the early articles is the appeal to familiar examples to establish a context when previous work is unavailable. Both Early-Y and Early-F begin by describing a general situation in which a hypothetical population becomes chaotic—in fact, both introduce the same nonlinear differential equation to describe the situation—and develop examples to launch their discussions of the properties of chaos. The equation they use is one of "the long-known classical equations of physics" (Baker & Gollub, 1990), and as such, is very familiar to their audiences. They start with a common exemplar to establish common ground and then invest it with new meaning, showing that the familiar situation has not accounted for chaotic properties.

We call these opening moves that use an example "Exemplar Moves." Examples remain common ground that can be shared both by researchers pursuing normal science and those attempting to launch a revolution or paradigm shift. Kuhn (1970) argued that although scientists on either side of a paradigm shift experience a communication breakdown over "the immediate past," they still share "most of their scientific world and language," specifically a set of exemplars (p. 203).

Although both Early-F and Early-Y appeal to exemplars in their opening moves, they vary in degree of departure from conventional moves. Early-Y incorporates many conventional-looking elements in the introduction and attempts to establish a context of interesting applications (Exemplar Move 1, S1-12) and previous work (Move 2, S14-16). However, the effort seems strained as compared with the more recent articles.

Published in 1975, Early-Y does not and perhaps cannot open with a claim of current interest in a familiar topic. However, the opening shows signs of efforts to look conventional. The opening sentences sound like a calculus textbook, defining differential equations as ways to describe changes in a population over time. This statement is illustrated by several applications, including predicting the infection rate of schoolchildren, the wear on drill bits, and the growth in insect populations. These applications are supported with citations to five articles, of which one is a self-citation and two are in press. The appeal to applications with citations resembles the Move 1 openings of the later articles, but the rhetorical force is different. The claim is not so much that the situations are of great current interest to researchers, but rather that such equations are realistic and plausible. In fact, the interest of such equations must be pointed out explicitly: Despite their apparent simplicity, such equations can describe "surprisingly complicated" behavior (S11). The claim offered in this move is not "this is interesting" but "this is science."

Similarly, Early-Y's attempt at a conventional literature review has a different rhetorical force from the normal Move 2. This move (S14-

16) consists of a discussion of four articles published in the early 1960s by the meteorologist Edward Lorenz. However, Lorenz's work is not assumed to be familiar; the articles are promoted as "fascinating," and several sentences and a figure are devoted to summarizing their gist. Another reference to the literature was tacked on to the very end of the introduction while Early-Y was in the proof stage of publication (S24); it refers to additional findings in an "independent" study (still in press) of similar systems. This late addition merely underscores the thinness of the historical cover. Both the thinness of current literature and the explanations of citations demonstrate the lack of an authorizing community and point to the need for a new approach to presenting the radical work.

Because so little relevant work had been done, it may have been impossible for Early-Y to point out a gap in an established line of research. Early-Y completely omits the gap (Move 3)—perhaps because it seems to be gaping—and goes directly from describing Lorenz's framework to the purpose statement. The outline of the project (Move 4b, S17-24) is clear but undramatic. It simply states: "In this paper we analyze a situation in which the sequence $\{f^n(x)\}$ is nonperiodic and might be called chaotic." At this early point in the history of chaos theory, neither Li and Yorke nor their audience seem to have formulated questions beyond, "What is this phenomenon?"

In contrast to Early-Y, Early-F clearly departs from conventions. It makes no reference at all to previous work. None of the article's seven references appear in the introduction (indeed only one citation actually appears in the paper). Instead, Early-F confines the opening move to describing the example of a dynamic system (Exemplar Move 1, S1-6). The next section develops in detail a formal model of the dynamics of this population example and provides a wealth of qualitative information about it (Exemplar Move 2, S10-66). The work in this section seems to be original and does not review or even refer to any previous research. Therefore, this section does not represent a conventional Move 2. Nevertheless, this material does provide background information—a comprehensive account of what can currently be understood about the topic under discussion. We have therefore categorized this section as Exemplar Move 2—introducing original background material.

Against this context, Early-F then creates a gap (Move 3, S67-68) by appealing to the locus of balance and by asking, in effect, "Given all this qualitative information, can we not also say something quantitative?" The specific purpose statement (Move 4b, S69-86) promises to "answer this inquiry in the affirmative." The project then focuses on the quantitative information, introducing more new information: the two now-famous constants or universal numbers for chaos (alpha and delta).

The Kairos of the Early Years of Chaos

Why does Early-Y take a more conservative approach and strain to follow the conventional moves, whereas Early-F shakes off the conventions? The answer may simply be a matter of timing. In her comparison of Avery's "premature"[2] 1944 article on DNA to Watson and Crick's "overdue" 1953 article on DNA, Miller (1992) argued that Avery's ability to fill the gap is constrained by kairos. Because Avery's work is "premature," he must work harder to create a context for his work. Miller noted, "Avery dwells on moves one and two, nearly omits three" (p. 322). Because the knowledge that Avery and his audience share—genetic material appears to be a protein—does not admit Avery's new finding—DNA is the genetic material—Avery has difficulty constructing a gap.

The context against which Early-Y was written seems to be similar. Though Early-Y cannot be seen as premature,[3] it addresses neither an established community nor an agreed-upon set of concerns. Therefore, formulating a gap seems to have presented difficulties. Yorke's stated goal in publishing Early-Y was to reach as many scientists, especially physicists, as possible (Gleick, 1987). This implies that Yorke is trying to create an audience where one did not yet exist. Like Avery's article, Early-Y seems to dwell on the early moves and skips the gap.

However, in the 3 years between Early-Y (1975) and Early-F (1978), several articles appeared on chaos theory, including a high-profile review article in *Nature* (May, 1976). Although Early-F still works hard at creating a context, the question the community wanted to answer had already been formulated: Do chaotic models provide quantitative information? With interest already stirred and big news to report, Feigenbaum could afford to act more boldly.[4]

Old and New Information in Early and Late Articles

In addition to differing in their conformity to the moves identified by Swales (1984), the introductions of the early and later articles also differ in their attention to old and new information. In this section, we examine the amount of space devoted to each move and the number and use of citations in these articles' introductions. This comparison indicates an increasing reliance in the recent articles on shared knowledge within a growing community of chaos scientists, a reliance that reflects conventional moves for linking new ideas to old.

Sentence Distribution

Figure 1 illustrates the amount of space (in sentences) devoted to old and new information. We defined as old information both the conventional Moves 1 and 2 that we saw in the later articles and the new Exemplar Moves 1 and 2 that we saw in the early articles. These moves are all designed to establish context and generate interest. We defined as new information material in Moves 3 and 4, which provide the exigence for and explanation of the new project. (For exact numbers of sentences per move, see bottom of Table 1.) The introductions of the later articles devote the most space to selling their new project, devoting 77% of all sentences in Later-Y and 63% in Later-F to Moves 3 and 4. On the other hand, the introductions of the early articles spend the most space on establishing a foundation for their research; 73% of the sentences in Early-F and 63% in Early-Y are in Moves 1 and 2. In short, the early articles seem to emphasize creating a context to make up for the lack of immediate shared knowledge whereas the more recent articles, because they are working within an established community, can focus on their own project.

In addition, Figure 1 demonstrates a difference between the authors: Early-F and Later-F devote about 10% more space to the Moves 1 and 2 than Early-Y and Later-Y. This difference may be a result of Feigenbaum's tendency to deviate more from the standard moves.

Citations

The early and later articles also differ in the use of citations (Table 1). The later articles have more total citations: Later-Y cites 23 articles, whereas Early-Y cites 17; Later-F cites 48 articles, when Early-F cites 7. Furthermore, the initial citations in the later articles are more likely to cluster in the introduction itself. None of the seven citations in Early-F occur in the introduction, but half of the 48 articles cited in

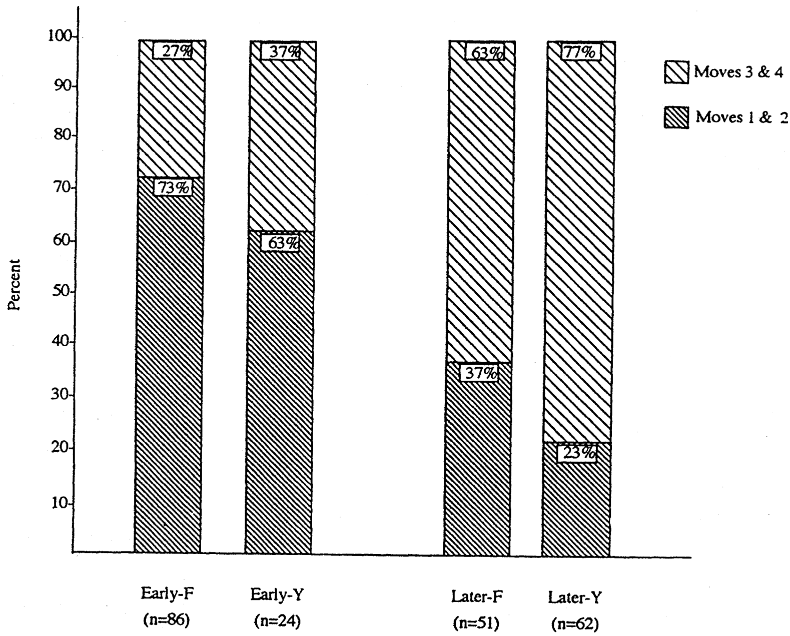

Figure 1: Percentage of sentences in Moves 1 and 2 (old information) and Moves 3 and 4 (new information) in early and later chaos articles.

Later-F are cited in the introduction. Similarly, the percentage of citations occurring in the introduction increases from .59 in Early-Y to .74 in Later-Y. As this increase indicates, by 1989, it had become possible and even necessary to connect new work in chaos to the immediate past of 15 years of chaos research. As Bazerman (1988) has argued, a writer's ability to use "explicit citation and implicit knowledge" reflects the state of the field (p. 25). The more the field develops, the more it allows for "the increasing embedding of arguments in a web of literature of the field" (p. 164).

In addition to changes in number, the citations in the recent articles are also less personal. In the early articles, most of the references use both a citation number and the name of the scientist cited; eight of ten references in the introduction of Early-Y are named in the text, including extensive comments about Lorenz. The one reference actually cited in Early-F is also named. However, the more recent articles omit

Table 1
Textual Features of Introductions in Two Early (E-F and E-Y) and Two Later (L-F and L-Y) Chaos Articles

	Chaos Articles				Percentage of Total			
	E-F	E-Y	L-F	L-Y	E-F	E-Y	L-F	L-Y
Citations								
Articles cited in intro	0	10	24	17	.00	.59	.50	.74
Articles cited elsewhere	7	7	24	6	1.00	.41	.50	.26
Total articles cited	7	17	48	23	1.00	1.00	1.00	1.00
Types of sentences								
Citations/elaborations	0	6.5[a]	9.5[a]	6	.00	.27	.19	.10
Equations/figures	19	3.5[a]	4.5[a]	3	.22	.15	.10	.05
All other	67	14	36	53	.78	.58	.71	.85
Total sentences in intro	86	24	51	62	1.00	1.00	1.00	1.00
Distribution of sentences								
Move 1 or E1 (topic)	6	12	2	1	.07	.50	.04	.02
Move 4a (purpose-general)	3	1	2	5	.04	.04	.04	.08
Move 2 or E2 (review)	57	3	17	13	.66	.13	.33	.21
Move 3 (gap)	2	0	10	3	.02	.00	.20	.05
Move 4b (purpose-specific)	18	8	20	40	.21	.33	.39	.64
Total sentences in intro	86	24	51	62	1.00	1.00	1.00	1.00

NOTE: E1 and E2 represent Exemplar Moves 1 and 2.
a. Sentences that contained both a citation and an equation were given .5 points in each category.

names and almost exclusively use numbers. The numerical citation system almost certainly saves space; we can only speculate that names were deliberately added in the early articles as an extra effort to establish community. In any case, the strategic value of the citations may be undermined by the numerical citation system, which seems to discourage mentioning prominent colleagues by name. Unless readers turn to the end of the article, they cannot tell whose work is being cited or even how many articles are being referred to. The superscript numbers used in the text to signal a citation do not directly reflect the number of articles being cited.

Interestingly, both of the later articles exploit the depersonalization of the numerical citation system by using nonobvious self-citations. Later-Y's gap is carved out of the recent progress made by reference 6. Reference 6 established two routes to chaos, abrupt and saddle-center bifurcation in chaotic scattering, but only investigated the abrupt route. Later-Y investigates the saddle-center route. The authors of reference 6 turn out to be two of Yorke's current coauthors and a third researcher. In the text, they are referred to as "the authors of reference 6" and as "they," whereas "we" is used for references to the current work. Of the 17 citations in Later-Y's introduction, four (or 24%) are by Yorke's coauthors. Similarly, Later-F cites theories for handling equimeasure partitions and praises them as "simple and elegant"; the citation turns out to be articles written by Feigenbaum and his coauthors. Of the 24 articles cited in Later-F's introduction, 12 (or 50%) are by Feigenbaum or his coauthors. These self-citations may be self-serving, or they may simply reflect the predominance of these researchers in a still new and relatively small field.

Types of Sentences

Finally, we counted the numbers of sentences of different types in the introductions. In addition to having more citations, the introductions of the later articles contain more sentences about previously published articles (middle of Table 1). Although Early-F contains no sentences that cite or elaborate on the previous literature, Later-F contains 9.5 such sentences out of a total of 51. The number of citation/elaboration sentences is equal in Early-Y (6.5) and Later-Y (6), but this accounting underrepresents the space devoted to previous research in the later article. Twelve sentences in Later-Y's Move 2 summarize previous work but are not counted in Table 1 because they cite no specific articles. Including them would bring the percentage to 29%.

As the space devoted to the previous literature in the introductions increases, the amount devoted to equations and figures, which were used to set up the exemplars in the earlier articles, sharply declines. As a proportion of the total number of sentences in the introductions, the later articles devote less than half as much space as the early articles to equations and figures. This decrease seems to reflect greater reliance on shared knowledge, in the form of both published literature and terminology for concepts that need no longer be built up from scratch.

Conclusion

As this textual analysis of the introductions of these early and more recent texts indicates, the ability to use the shared knowledge of an established community affects scientists' ability to create a context on several levels. Scientists promoting radically new ideas must create new methods of constructing a context for their work. In the early articles, both scientists use a strategy for establishing context that has not received much attention. They rely on a common example rather than relying on claims of current interest. This approach is not adopted by scientists migrating to a different but established field, who typically appeal to the values and goals of the field and use citations to establish their familiarity with it (Blakeslee, 1993; Myers, 1985). As we have argued, the relatively spare use of citations in the introduction of the early articles does not indicate less care in the structuring of the arguments, especially given the space dedicated to these new moves; it reflects the situation of creating a new discipline rather than moving in on an established one.

RECEPTION OF CHAOS ARTICLES BY SCIENTIFIC READERS

Having found that the introductions of the early articles depart from the conventional moves in distinct ways, we were also interested in whether these articles might evoke different reactions among scientists than do the later articles. Obviously, readers today cannot read the early articles in the same way as readers at the time of publication. What was new then is familiar now, so some ideas that were radical then may seem trivial now. The major authors, Feigenbaum and Yorke, are much more prominent now than they were 20 years ago, so readers now may be more tolerant of departures from convention. Although we cannot reconstruct how readers reacted when the early articles were first published, we can explore how such variations in novelty and in structure influence contemporary readers.

We do know that, despite their unconventional introductory moves, the early articles succeeded in reaching wide audiences. As of September 1994, Early-Y had been cited 432 times and Early-F a whopping 1,137 times. These numbers are particularly impressive given that the average scientific paper is cited only once or twice per year; from 1945 to 1988, only 2 in 10,000 scientific papers were cited more than 500 times in their lifetimes (David Pendlebury, Institute for Scientific Information, personal communication). The later papers, both of which appeared in the same prestigious journal within a year of each other and both of which have high-profile authors, are also achieving more than average success: Later-Y has already been cited 21 times in just over 4 years (or 5.3 a year) and Later-F more than 42 times in nearly 6 years (or 7.0 a year).

What these citation counts do not reveal is how readers respond to the individual rhetorical strategies we have traced. We observed 12 scientists reading the four chaos articles and thinking aloud as they read. A comprehensive account of the scientists' reading activities is beyond the scope of this study. Rather, our goal is to explore how the introductory moves influenced the scientists' reading processes by tracing their reactions at each rhetorical move.

Our selection of the early articles and their authors was in part predicated on their importance. If these early articles had not succeeded, we might not have been able to use chaos as a test bed for examining how rhetorical strategies develop as new fields become more accepted.

Method

Participants

The participants were 12 faculty members at two large state universities: six full, two associate, and four assistant professors. They represented various scientific and technical disciplines in which chaos has had important applications: physics (four participants), engineering (three), mathematics (three), ecology (one), and meteorology (one). The participants all identified themselves as involved in some way in chaos work, by regularly reading journal articles (especially in *Physical Review A*, where the two later articles appeared), conducting research, or teaching classes on chaos theory. Most had heard of Feigenbaum, and some had heard of Yorke. Four had had earlier contact with at least one of these articles, having heard it at a conference or read it.

Procedure

We asked each participant to read two of the four chaos articles. They read articles that were paired either from the same time period

(Early-F and Early-Y; Later-F and Later-Y) or from the same author (Early-F and Later-F; Early-Y and Later-Y). Three participants were randomly assigned to each of these four pairings, so each article was read by six participants.

We told the participants that we were interested in observing what professional scientists did as they read articles related to their work. We asked them to read the articles as normally as possible except that, to enable us to observe and record what they did, they were to think aloud as they read. They were asked to read aloud and to say aloud whatever thoughts went through their heads. They were told that the purpose of the commenting was not to explain the text to us or to describe what they were doing, but simply to come to terms with it for themselves as they normally would. They were also given an opportunity to practice thinking aloud on a brief passage from a separate text. Participants were then given two articles and allowed to choose one to start with.

To encourage participants to read at a normal pace, they were told that they would not have time to read all of both articles but that they could keep the articles if they desired. Although our main focus was the introductions, we did not explicitly direct participants' attention to the introductions because previous studies indicated that scientists frequently read nonlinearly (Bazerman, 1988; Charney, 1993; Dillon, Richardson, & McKnight, 1989; Wyatt et al., 1993). The participants read the first article for about 25 minutes, then, at the nearest textual break, they were told to begin the next article. They then read the second article for about 25 minutes. Within that time frame, most participants had turned to and read the introduction. Three participants had skimmed selectively through the introduction (only one of these skipped it altogether), so at this point we asked these three to go back and read it. The reading-aloud sessions were followed by open-ended interviews.

These procedures allowed us to investigate how readers allocate their time during a period of concentrated reading. The situation is somewhat artificial, of course, given that we chose the articles they would read. We cannot, therefore, comment on what leads scientists to seek out certain articles or to decide not to read an article at all. These procedures were flexible enough, however, to allow readers to respond to the texts in their own way. Some of our readers got bored with the texts, others frustrated, and said so. Some stopped, others skimmed, and several skipped around.

Coding of Comments

The tapes of the reading-aloud sessions were transcribed and segmented into commenting episodes. Most episodes were bounded by direct reading from the text. Where participants made lengthy comments after reading a portion of text, a new episode was marked if the reader shifted focus or changed topics. The comments were categorized according to a coding scheme based on Charney (1993), which distinguishes basic reading comprehension activities (coming to terms with the text on a fairly literal level) from rhetorical activities (judging the text, the validity of the ideas, their relevance or significance). One of us coded all of the comments according to this scheme; a second independent coder recategorized half the comments from each participant, including selections from both articles. The intercoder reliability was acceptable: $K = .71$, $N = 421$, $p < .01$, by Cohen's kappa. Although readers read and commented on the article titles and abstracts and a few read scattered bits of text beyond the introduction, we are confining the analysis to the introduction.

Results

Our first goal was to see whether some moves were more important than others by investigating whether readers concentrated their comments in particular places. We assumed that important moves elicit more comments than unimportant moves. However, simple quantities of comments are difficult to compare fairly. Some readers were more verbose than others. Some moves were lengthier than others. In order to find the fairest points of comparison, we used several methods to identify provocative sections: (a) calculating simple distributions of comments across moves per reader and factoring in the number of sentences in a move, (b) identifying "hot spots" that attracted considerable attention from all or most readers, and (c) determining what types of sentences attracted the most attention.

Distribution and Rate of Comments

The first method was simply to count the comments from all readers and note how they were distributed across the moves. Figure 2

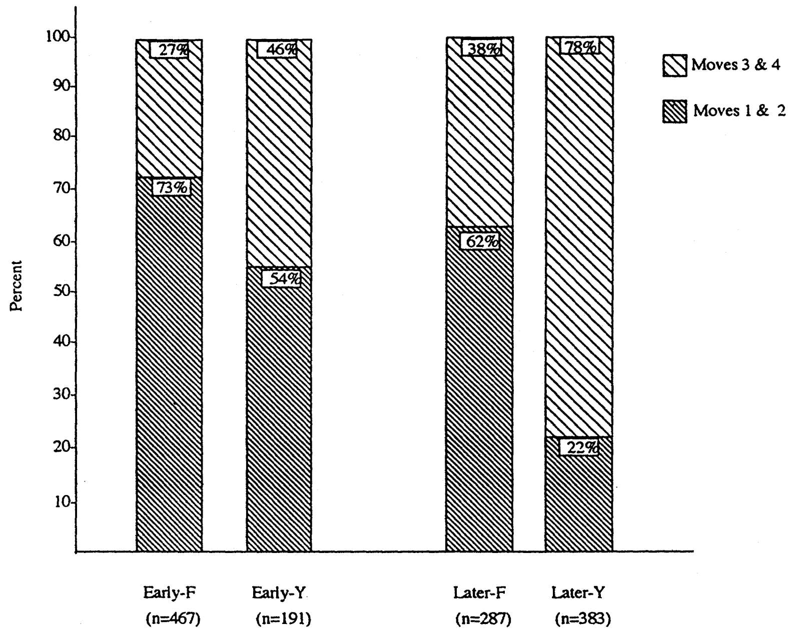

Figure 2: Percentage of scientists' comments while reading Moves 1 and 2 (old information) and Moves 3 and 4 (new information) in early and later chaos articles.

illustrates how readers allocated their comments between parts of the introduction dealing with old information (Moves 1 and 2) and new information (Moves 3 and 4). For two of the articles, Early-F and Later-Y, the distribution of the comments exactly mirrors the distribution of sentences (compare with Figure 1). If readers make comments at a steady pace, this is what we would expect. However, Early-Y has somewhat fewer comments than we might expect in the old moves, given the space devoted to them. Later-F attracted more comments in Moves 1 and 2 than might be expected; 62% of the comments are made in these moves that focus on old news, even though only 37% of the sentences are found there. The large number of comments may indicate that the readers had difficulty reading the text or found it especially provocative.

However, at this fairly gross level of analysis, it is difficult to tell whether the number of comments simply depends on the length of

Table 2
Distribution of Readers' Comments and "Hot Spots" Over Introductory Moves in Early (E-F and E-Y) and Late (L-F and L-Y) Chaos Articles

	Proportion				Per-Sentence Rate[a]			
	E-F	E-Y	L-F	L-Y	E-F	E-Y	L-F	L-Y
Distribution of comments								
Move 1/E1 (topic)	.08	.42	.06	.04	6.7	6.8	8.0	7.0
Move 4a (purpose-general)	.03	.02	.02	.07	4.7	4.0	3.5	5.0
Move 2/E2 (review)	.65	.12	.56	.18	5.3	7.7	9.5	5.2
Move 3 (gap)	.02	.00	.20	.10	3.5	0.0	5.6	13.0
Move 4b (purpose-specific)	.22	.44	.16	.61	5.8	10.4	2.3	6.0
Total comments	1.00	1.00	1.00	1.00	5.4	8.0	5.6	6.2
Distribution of hot spots								
Move 1 or E1 (topic)	.07	.60	.08	.05	.16	.25	.50	1.00
Move 4a (purpose-general)	.00	.00	.00	.00	.00	.00	.00	.00
Move 2 or E2 (review)	.73	.20	.50	.25	.19	.33	.33	.42
Move 3 (gap)	.00	.00	.25	.10	.00	.00	.33	.66
Move 4b (purpose-specific)	.20	.20	.17	.60	.16	.12	.10	.31
Total hot spots	1.00	1.00	1.00	1.00				
Hot spots by sentence type								
Citations/elaborations	.00	.30	.37	.15	.00	.20	.47	.50
Equations/figures	.60	.50	.13	.10	.47	.71	.33	.66
All other	.40	.20	.50	.75				
Total hot spots	1.00	1.00	1.00	1.00				

NOTE: Twelve scientists each read two articles, for a total of six readers per article. Comments include comprehension, evaluation, genre, and metacomments. Hot spots are sentences about which more than 80% of current readers commented at least once, or about which more than 50% of current readers made at least 10 total comments. E1 and E2 represent Exemplar Moves 1 and 2.
a. The per-sentence rate is the number of comments or hot spots divided by the total number of sentences in that category, as listed in Table 1. For example, for Early-F, Move E1 had six sentences that elicited 40 comments, for a rate of 6.7 comments per sentence, and one hot spot, for a rate of .16 hot spots per sentence.

the text. The effect of length can be examined more directly in Table 2. The left side of the table presents the average proportion of comments subjects made in each move. In all four articles, the largest proportions of comments occur in either Move 2 (Early-F and Later-F) or Move 4b (Early-Y and Later-Y). In Early-Y, equally large proportions of comments occur in Move 4b and Exemplar Move 1. These proportions do not account for the lengths of the text in these moves. We therefore calculated a per-sentence comment rate (right side of Table 2), dividing the number of comments by the number of sentences in that move.

We then examined the articles for above-average rates of commenting, where the average rate was calculated at six comments per sentence (or one comment per sentence per reader). In all four articles, Move 1 attracts an above-average rate of comments and Move 4a a below-average rate. The rate for Move 2 is above the average for two articles—but these are from neither the same author nor the same time period. The rate for Move 3 is above average for only one article. The rate for Move 4b is at or above average for both of Yorke's articles. The proportions and rates coincide with the provocativeness of several moves, but only the rate measure marked Move 1 as a significant move.

These measures indicate no systematic differences between the early and later articles. However, the two Yorke articles attracted above-average comments overall. Early-Y attracted the highest rate of comments per sentence (a rate of eight), with above-average comment rates for three moves. Later-Y had above-average rates for two moves. In contrast, the overall rates for the two Feigenbaum articles were just below average. In Early-F, which most readers considered the most important article and which least followed the conventional moves, only Move 1 had a higher-than-average rate of commenting.

Distribution and Rate of Hot Spots

As a second, more conservative way to identify particularly provocative text segments, we also identified a set of "hot spots." A sentence was counted as a hot spot if more than 80% of current readers commented on it at least once, or if more than 50% of current readers made at least 10 total comments about it.[5] Because this measure accounts for the number of readers commenting, it is less susceptible to skewing from a few very talkative readers than is the distribution of comments. Sentences that catch the attention of all or most readers may be the most generally provocative or difficult text segments. The lower portion of Table 2 presents the proportion of hot spots per move in each article and the rate of hot spots per sentence. A total of 52 of the 223 sentences in the four introductions were identified as hot spots for an average of rate of .25, or one in every four sentences.

The results in Table 2 indicate that some moves produced more hot spots than others. Consistent with the results presented above, Move 4a appears not to be an important move, as Move 4a produced no hot spots in any article. However, as in the previous analysis, Move 1 appears to be an important move; the rate of hot spots is at or above average for three articles (all but Early-F). For the same three articles, Move 2 attracts above-average rates of hot spots. Moves 1 and 2 appear to be highly significant moves.

The hot spots also reveal some differences between the early and later articles. For both authors, the rate of hot spots in Moves 1 and 2 is higher in the later than in the early articles. Another contrast between the early and later articles is the rate of hot spots for Moves 3 and 4. Neither early article had any hot spots in Move 3, presumably because (as noted in the textual analysis) neither one pointed to a gap in the existing literature. In contrast, in both later articles, Move 3 attracts a higher-than-average rate of hot spots, with an especially high rate for Later-Y. Only Later-Y has an above-average rate of hot spots in Move 4b.

By the hot-spot measure, then, the most provocative article is Later-Y, with above-average hot-spot rates for all moves (except Move 4a), whereas the least provocative article is Early-F, with no above-average rates for any moves. This pattern is clear in Figure 3, which combines the rate of hot spots per sentence for old information (Moves 1 and 2) and new information (Moves 3 and 4). Later-Y clearly receives the most response and Early-F the least. Even at points of new information, which get little response in the other articles, Later-Y draws a hot spot almost every third sentence, nearly double the response Later-F gets to the new information. In fact, both of Yorke's articles appear to be more provocative than Feigenbaum's.

Finally, Figure 3 supports the finding that the old information provokes more comments than the new information. Although this is true for all four articles, the later articles provoke considerably more hot spots in Moves 1 and 2 than do the early articles. For Moves 1 and 2, a rate of .37 in Later-F compares with a rate of .19 in Early-F, and a rate of .43 for Later-Y compares with .27 for Early-Y. We explore some explanations for this result when we consider the content of the readers' comments.

The Provocativeness of Citations and Equations

Finally, we examined the distribution of hot spots to see if they clustered in sentences with citations or elaborations on previous research or in sentences that contained equations or figures (Table 2).

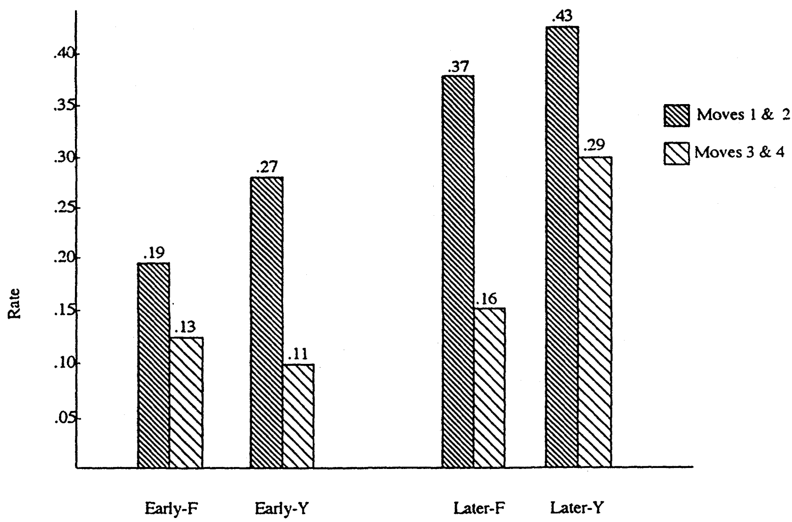

Figure 3: Rate of hot spots per sentence in Moves 1 and 2 (old information) and Moves 3 and 4 (new information) in early and later chaos articles.

Sentences containing citations and elaborations accounted for a substantial number of hot spots. None of these occurred in Early-F, for the obvious reason that the introduction contained no citations. However, citation sentences accounted for more than 30% of the total hot spots in Early-Y and Later-F and for 15% of the hot spots in Later-Y. The rate of hot spots in these sentences was also high: In the later articles, half of all citation/elaboration sentences were hot spots. The high rate of hot spots for citation/elaboration sentences corresponds to the high rate of hot spots in Moves 1 and 2. These may be two ways of representing the same phenomenon: that readers pay a great deal of attention to the relationship of new ideas to the previous work. Alternatively, the location of these citations in these moves may be significant. To tease apart these possibilities, we would have to look at the rate of hot spots on citation sentences in other locations in the article, data that are not available in this study.

Many of the hot spots contained equations and figures, especially in the earlier articles. In Early-F, 9 of the 15 hot-spot sentences (or 60%) contained equations or figures, and in Early-Y, 2.5 of the 5 hot spots (50%) were equations and figures. In contrast, fewer of the hot spots in the later papers were accounted for by equations and figures. Equations and figures accounted for only 1.5 of 12 hot spots (or 13%)

in Later-F and only 3 of 20 hot spots (or 15%) in Later-Y. As the right side of Table 2 indicates, the drop in attention to equations and figures in the later articles was not simply a result of having fewer equations and figures to comment on. Rather, readers were drawn to comment on equations and figures at a substantial rate in both early and later articles. In Early-F and Later-F, about 40% of all sentences with equations and figures were hot spots; in Early-Y and Later-Y, about 68% of these sentences were hot spots. These results suggest that the equations and figures were doing more rhetorical work in the early articles—a point that is consistent with the earlier textual analysis. In the absence of extensive publications to cite, both early articles use equations and figures in their Exemplar Move 1 to describe the example population system that establishes the topic. Neither later article resorts to equations or figures in Move 1. In fact, in Later-Y, equations and figures appear only in Move 4b.

Content of Comments

The distribution of comments indicates that readers did not simply comment at a steady pace, say every other sentence, regardless of the rhetorical purpose of the material they were reading. The results suggest that readers devoted great attention to the moves that created context, Moves 1 and 2. The numbers of comments, however, tell us little about their actual reactions. In this section, we examine the content of the comments to see whether readers responded to the rhetorical intent of each move.

When we examined what readers were actually saying, our first concern was what type of comments they were making. Most of the time, readers were deeply involved in simply comprehending the text. Two-thirds of all comments fell in the comprehension category, which included rereadings, paraphrases, inferences, and so on. Only 20% of the comments were evaluative reactions to the substance of the text. Ten percent were comments on the genre or form of the text, and the rest were comments on the reading task. The amount of attention to comprehension is not surprising, especially given the complex technical nature of these articles and the diverse backgrounds of the readers. Other studies (e.g., Charney, 1993) have found that professional readers spend much of their time on comprehension.

In what follows, we focus on the evaluative comments. We found evidence that readers did recognize the rhetorical force of the introductory moves. We also observed that all were deeply engaged in efforts to relate the texts to their own work.

Old Information: Moves 1 and 2

The distribution of comments indicates great attention to Move 1. The readers' comments support the idea that in all four articles, Move 1 is doing its job—attracting interest. In fact, our readers both explicitly and implicitly recognized the function of Move 1. While reading the opening of Later-Y, which lists the "situations of practical interest" in which chaotic scattering occurs (S1), one reader commented, "This is the standard stuff everyone starts with" (Reader 4 [R4]). Another said, "They are starting off with PR and this is standard for a physics paper, a sales pitch" (R3). These comments suggest not only that this kind of opening is common, but also that it is sometimes seen as vacuous or as self-serving.

Other Move 1 comments, however, indicate that readers use the information in a list of applications and citations to make decisions about whether the article is worth reading closely or at all. Three readers of Later-Y used the list of applications and citations in S1 to assess whether the topic fell within their ken. One recognized both topics and citations as familiar: "So we got chaotic scattering and molecular dynamics which I should know about. And the references to Noid, Gray, and Rice, two of which I know. Not so sure about Gray" (R8). Two others commented that the list of applications was not closely related to their interests, one commenting, "OK, so I know we're really, we're not talking about wave scattering like I'm used to. We're talking about classical particle scattering. So that at least keys me to what these guys are talking about" (R5).

Two of the other articles, Later-F and Early-Y, also contain lists of applications of the topic with citations. Two readers of Later-F commented on the importance in their own research agendas of multifractals, mentioned in S1 ("which I need to learn more about" [R9]), and their applications in S2 ("I should really know about that" [R12]). Even though Early-Y seemed to strain to supply some evidence of applications (S6-S7), two readers commented on them. For one, predicting the wear on spinning drill bits was an unfamiliar application of this equation (R11). Another recognized it as similar to problems in his own domain: "These equations can be used for many things. Like the spinning bits, [that] also comes up a lot in ecology" (R10).

In commenting on these moves, readers repeatedly questioned whether these articles were relevant to their work and whether these articles were really addressed to them. Moves 1 and 2 help to establish which readers are likely to find this work relevant; the terms in these moves identify what goals the community shares, what findings are taken as given, and what faces should seem familiar.

The readers' interest in establishing the relevance of these articles to their own work may help to explain why we found more hot spots in Moves 1 and 2 in the later articles than in the early ones (Figure 3). In the later articles, these moves conform more closely to the conventions and thereby provide more information that the readers can use to address their concerns about relevance. We would argue that this convergence is not accidental. The growth of interest in chaos in the years between the early and later articles not only provides the literary context that Feigenbaum and Yorke can invoke in Moves 1 and 2, but it also accounts for the presence of readers with research agendas that may overlap with theirs. The hot spots are places where all or most readers commented. In an interdisciplinary science such as chaos theory, the old news may be the only area that readers share and where all readers must decide on the relevance of the theory to their own work.

The same concerns were evident in comments about Move 2. However, in this move we also saw more concern with validating the information being presented as shared. Here more than elsewhere, readers made comments like "I'm familiar with that" or "as usual." These readers recognized the purpose of this section as presenting "old news," and they largely accepted the authors' characterizations of the past research as accurate and uncontroversial.

Some readers, in fact, were bored by the lack of news in this move and declined to spend time reading it. For example, even though five of the six readers of Early-F were familiar with this article and its importance, and three had explicitly commented on its interest, only two readers read through Exemplar Move 2, the unusual and long move in which Feigenbaum carefully builds up the qualitative information available using then-current methods of analysis. Two readers (R9 and R10) read only a line or two, sometimes only a word or two, before skipping ahead, with R10 commenting, "I'm familiar with that." Another reader started out reading closely, but after several comments about the low news value ("I don't need this. I don't see why he's spending so much time trying to develop this model when it doesn't have anything to do with reality anyway.") skipped through the remainder looking for a discussion of the famous alpha constant, which she knew was introduced in Feigenbaum's early work. Even one of the readers who did work though this move stated halfway through, "Right, let's get to the good stuff" (R12).[6]

The old information is really old in the early articles, which might also help explain why the early articles had fewer hot spots in Moves 1 and 2 than the later articles (Figure 3). The old information in the later articles helps readers decide on the relevance of the article to their current work. The old information in the older articles is too distant and too established to be of use.

New Information: Moves 3 and 4

Given the importance of the gap in motivating the new work, we originally expected Move 3 to attract more attention from readers. We did find that readers recognized the functions of Move 3 and Move 4b, identifying a gap in the literature and filling it. For example, at the opening of Move 4b in Later-Y, the authors announce the goal of investigating saddle-center bifurcations, which reference 6 had postulated but had not pursued (S23). At this point, R4 commented, "Most of the time when scientists write, they always critique other people, make them look stupid, so they look smarter in comparison. That is completely unnecessary in this context." Reader 4 went on to acknowledge, however, "This is a very, very important question they try to answer." Another reader also recognized Move 4b at the same point (S23), but interprets it differently:

> OK, well my feeling is that this is a fairly, uh, straightforward kind of thing these guys are doing . . . they're improving on somebody else's work. And if I were a guy working in this field I might find this paper worth reading, but it is really a mathematician's kind of paper. Let's see . . . I am trying to convince myself that there is something that I want to learn from this paper. (R5)

Both readers recognized Moves 3 and 4 as claiming to be doing something that others have left undone, but they differed in their interpretation of the motives. Reader 4 saw the move as self-promotion; R5 saw it as part of a cooperative enterprise that he's not sure he shares.

Interestingly, in viewing the purpose in Later-Y as building on old work, neither of these two readers recognized that reference 6 was a self-citation to the work of Yorke's coauthors. Reader 5 attributed reference 6 to "somebody else"—this reader had noted the citation mark but did not at that point turn to examine the reference list.[7] The other reader, R4, did try to identify reference 6, but failed to recognize the authors: "What is reference 6? It's a bunch of guys who wrote *Physical Review Letters*. Articles in *Physical Review Letters* always tend to get critiqued a lot. People tend to argue against them rather heavily, like their ego is involved. I wonder why" (R4, at S21). Two other Later-Y readers recognized without additional comment that the citations referred to previous work of the authors. Readers seem to have a default assumption that Move 3 points out a gap in the work of "somebody else." This does not mean that building on one's own work is considered inappropriate. Later-F also had a self-citation, referring to "simple and elegant theories" (S13) that did not apply to the new situation of interest. Only one reader checked the reference page while reading this sentence and saw nothing unusual with the self-citation: "That's in [references] 11-13. Who did that? [Flips back to references.] Oh, that's all Feigenbaum, I had no idea he was doing this kind of stuff. I haven't paid attention to what he's up to" (R9). Although both authors use similar approaches with the citation, the gap in Later-Y is explicitly drawn out, whereas in Later-F the gap is implicit.

Later-Y seems to be the most successful article at holding most readers' attention throughout the introduction, all the way into Move 4b. Considering that both Later-Y and Later-F should be topical for current readers, the difference may be due in part to Later-Y's very clear exposition of the moves, especially the gap (Move 3). Three of the six readers of Later-Y commented on the interest of the research question while reading Move 3. In contrast, only one of Later-F's readers did so at the end of Move 2, and his remark was negative: "My suspicion very right down deep is that this is somehow not as dramatic as it sounds" (R9).

These comments suggest that the quality of the research question and the clarity of the exposition of that question influenced readers' investment in these later moves. The research problem in Later-Y is more clearly laid out than in Later-F, which might explain why Moves 3 and 4 in Later-Y provoked nearly twice as many hot spots as in Later-F. Overall, Moves 3 and 4 produced fewer comments than

Moves 1 and 2, even in later articles where these moves accounted for more of the total space in the introduction (Figure 1). These moves also concern a narrower topic than the early moves. Our diverse group of readers may have needed more specialized knowledge about the specific research project to comment on it at any length.

CONCLUSION

In this study, we combined a textual analysis of scientific journal articles with an observational study of how textual features influence the reading process.

Our textual analysis of early and recent articles in chaos theory produced three major contrasts. First, we found that in the early days of chaos theory, when no literary context existed, scientists used a qualitatively different opening move—exemplars—to establish common ground with their readers. The same authors showed great facility with the conventional moves once the literature had developed. Second, they used more space in the early articles to establish this common ground because they lacked the disciplinary shorthand provided by citations to the literature and other shared terminology and concepts. Finally, consistent with these results, scientists relied more heavily on equations in the early articles and on citations in the later articles.

The appeal to disciplinary exemplars allowed the chaos theorists to aim for a broad audience of general scientists rather than appealing to the narrow research concerns of a specialized field. This strategy contrasts with that commonly adopted by scientists who migrate to a different, previously established field and attempt to sound like insiders by displaying their familiarity with its specialized terminology and literature. Although this difference demonstrates specialized approaches to varying rhetorical situations, it still argues for the importance of a context—the need to connect new projects to established information.

The observational study of readers confirmed the importance of establishing common ground. Both quantitative analysis of the distribution of comments and qualitative analysis of their content indicated that the readers' first concern was whether they could relate the reading to their prior knowledge and to their own work. Regardless of when an article was written or who wrote it, readers attended more to the context-setting information than to the description of the new project.

Given the readers' goal of establishing the relevance of the article to their own work, the early and recent articles did evoke different responses. Readers commented more on the old information in Moves 1 and 2 in the later articles than in the early articles. Similarly, the new information in the later articles was more interesting to them than the information that had been new 20 years ago.

Differences due to writing quality and the intrinsic interest of the research also emerged. Although these conclusions are more speculative, we can illustrate these differences by contrasting two articles, Early-F and Later-Y.

Early-F was not only the most famous and important article but also the one that departed most from the introductory conventions. Early-F contains the longest introduction (86 sentences), with a long and involved discussion of an exemplar in Moves 1 and 2. Interestingly, this introduction provoked less commentary overall than the other articles, as measured by the per-sentence rate and the below-average rate of hot spots in any move. The comments that the readers did make were largely devoted to comprehension, amounting to nearly 80% of their comments.

We speculate that because of Feigenbaum's reputation and because of the seminal place of his early article in the history of chaos theory, our readers were willing to devote extraordinary effort to comprehending Early-F. It is unlikely that most articles that depart so far from the scientific mainstream—as well as from conventional rhetorical structures—receive this kind of intensive scrutiny. In most cases, scientists who see no direct connection to their own work or no intrinsic interest in the problem simply stop reading. It is impossible to say how readers reacted to the article when it first appeared; given the experience of our self-selected chaos devotees, we can only attribute the extraordinary success of this article to the quality of its major contributions—the discovery of two crucial chaos constants—and to its fortunate timing.

In contrast, the article that most closely followed the conventional moves, Later-Y, provoked the most commenting activity in every significant move, with a much smaller proportion devoted to comprehension (only 62%). In the case of Yorke, we are dealing with an author who is less famous (according to our readers), though still much more successful than usual. Yorke seems to have made a concerted effort in both articles to follow the conventional moves as much as possible.

These efforts—and the intrinsic interest of the project—may have paid off in drawing readers through the full introduction. Even readers who were initially skeptical about the interest or relevance of the project commented on the importance of the question proposed in Moves 3 and 4. Later-Y was the only article to hold most readers' attention through the final Move 4b.

No one factor in this analysis seems decisive in the success of a scientific article. We cannot neatly tease apart the exposition of the text, the reputation of the author, the rhetorical situations of its publication and its readings, and the intrinsic quality of the project. The advantage of the method we have used, however, is that it brings all of these factors into play. Our approach challenges simple post hoc readings of successful revolutionary texts that often presume that the great scientist must also be a great rhetor. Such readings argue from the success of the text to the efficacy of whatever features they identify. It is a small step further to attribute these features to the intentional strategies of the author. In contrast, our analysis problematizes the causes of scientific success by recognizing the dynamic interplay of factors: the author's individual talent and communal validation through readers and the potential value of a scientific concept against its kairos.

APPENDIX A
Introductory Moves in Later-Y Article (Ding, Grebogi, Ott, & Yorke, 1990)[8]

Paragraph numbers are indicated in the left margin; sentence numbers are indicated as (S1), (S2). Paraphrases of the text are italicized. E1 and E2 represent Exemplar Moves 1 and 2.

Move 1: Demonstrate Interest in Topic

¶1 (S1) Chaotic scattering occurs in a variety of situations of practical interest, including satellite encounters in celestial mechanics,[1] molecular dynamics,[2] vortex pair scattering in fluid dynamics,[3] and classical potential scattering of point particles.[4-6]

Move 4a: Present Goal of New Work—General

¶1 (S2) In this paper we consider scattering from potentials which depend on some set of parameters. (S3) For example. . . . (S4) Given such a situation

(continued)

APPENDIX A Continued

it is natural to ask how chaotic scattering arises and evolves when these system parameters are allowed to vary. (S5) That is, given a set of parameters where the scattering is regular (i.e., not chaotic), what are the typical sequences of events ("routes") that occur as parameters are varied and the scattering becomes chaotic? (S6) This is the question addressed in the present paper.

Move 2: Review Previous Research

¶2 (S7) Most of the previous work on chaotic scattering has concerned systems with fixed potential parameters and fixed scattering particle energy. (S8) This past research has clarified the phenomenology of chaotic scattering, the structure of the fractal invariant sets, and the role of unstable periodic orbits in determining the scattering process. (S9) In particular, some of these results are the following. *S10-S19 summarize previous results; no specific articles are cited.*

Move 3: Point to Gap

¶3 (S20) Recently, some progress has been made on the general problem we address in this paper: understanding how and why scattering can become chaotic as a parameter is varied.[5,6] (S21) In Ref. 6 the authors argue that the onset of chaotic scattering can be achieved either through a saddle-center bifurcation or through another, new type of bifurcation which they call an abrupt bifurcation and that, for two degrees of freedom systems, these are the only two generic routes to chaotic scattering. (S22) They performed detailed analysis of the abrupt bifurcation but did not investigate the consequences of the saddle-center bifurcation route to chaotic scattering.

Move 4b: Present Goal of New Work—Specific

¶3 (S23) In this paper we study the saddle-center bifurcation route by investigating a particular model scattering problem and use the results so obtained to draw some general conclusions.

¶4 (S24) We show how the onset of chaotic scattering can be obtained via a saddle-center bifurcation, and we demonstrate how the character of the chaotic scattering process changes as the parameter is varied. *S25-S56 present a sequence of events from regular to chaotic scattering with reference to a situation illustrated in a figure referred to in (S34) and defined with two equations (S36) and (S39).*

¶8 (S57) The organization of our paper is as follows. (S58) In Sec. II we introduce our numerical techniques and discuss regular scattering and its characterization. (S59) In Sec. III. . . . (S60) We emphasize. . . . (S61) In the same section. . . . (S62) In Sec. IV we summarize our results and conclusions.

APPENDIX B
Introductory Moves in Later-F Article (Feigenbaum, Procaccia, & Tél, 1989)[9]

Move 1: Demonstrate Interest in Topic

¶1 (S1) Ever since it has been recognized[1-4] that fractal objects appearing in complex and nonlinear systems are not well characterized by a single scaling exponent, but rather by a spectrum of scaling exponents, there has been an explosive interest in such objects, which were termed multifractals.[3] (S2) Multifractals play a dominant role as strange attractors of chaotic dynamical systems,[5] dissipation fields of turbulent flows,[6] in growth patterns,[7,8] nonlinear resistor networks,[9] etc.

Move 4a: Present Goal of New Work—General

¶1 (S3) The aim of this paper is to work out in detail a powerful technical tool for the study of multifractals, a tool that allows calculations of relevant scaling properties from solutions of appropriate eigenvalue equations. (S4) For dynamical systems, this tool unifies the treatment of sets at the borderline of chaos with that of systems in their chaotic regime.

Move 2: Review Previous Research

¶2 (S5) The objects under study are usually fractals that support some measure. *S6-S10 describe a fractal set within a chaotic system and "fractal measures" for calculating probabilities of occurrences within some partition of the system, defined by Equation 1.1.* (S11) It has been shown further that the function $\tau(q)$ furnishes important information about the scaling properties of fractal measures. (S12) In particular a Legendre transform of $\tau(q)$ yields the $f(a)$ function, a very convenient representation of the scaling properties of fractal measures.[4]

¶3 (S13) Simple and elegant theories to calculate $\tau(q)$ [or, in fact, its inverse function $q(\tau)$], have been developed when the partition is an equimeasure partition. . . . 11-13 (S14) Such a situation occurs, for example, at the nth generation of refinement of the partition. *S15 transforms Equation 1.1 into Equation 1.2. S16-S17 generalize Equation 1.2, creating Equation 1.3.*

¶4 (S18) Inspecting Eq. (1.2) or (1.3) one notices the resemblances to the statistical mechanical relation *Equation 1.4 [in which* G(B) *appears in an analo-*

(continued)

APPENDIX B Continued

gous position to q(τ) *in equations 1.2 and 1.3]* where *G(B)* is the free energy (density) multiplied by the inverse temperature *B*. (S19) Indeed, this resemblance gave rise to the development of the thermodynamic formalism of multifractals.[14,15] (S20) In particular $a^{q(\tau)}$ can be calculated as the largest eigenvalue of a transfer matrix of an appropriate spin model whose thermodynamics is equivalent to that of the given fractal measure. (S21) Nonanalyticities in $q(\tau)$ could be interpreted as phase-transitions.[16-19]

Move 3: Point to Gap

¶5 (S22) If the partitions are not equimeasure partitions, $q(\tau)$ cannot be calculated in this way. (S23) Still the rate of growth of the sum *[function from Equation 1.3]* is an important piece of information on the multifractal set, shedding light on its geometric rescaling factors. (S24) To avoid confusion with $q(\tau)$ *we shall adopt a different notation for this rate of growth, a notation that follows standard thermodynamics. (S25) We shall write Equation 1.5 [which transforms Equation 1.3 by replacing the* q(τ) *expression with a similar* G(B) *expression].* (S26) *G(B)* might depend on the partition. (S27) For point sets organized on regular trees, we shall use the coverage defined in Sec. II. *S28-S29 discuss required correspondences between the terms* G, B, *τ, and* q. (S30) In fact, for the generating partition of hyperbolic systems –*G(B)* is a quantity called pressure in the mathematical literature of thermodynamic formalism and has extensively been studied.[14,15] (S31) The sum (1.5) has already been investigated for nonhyperbolic systems, too, and it has been found that *G(B)* can have nonanalyticities (phase transitions) as well.[20]

Move 4b: Present Goal of New Work—Specific

¶6 (S32) The theory developed below is aimed at calculating the function *G(B)*. (S33) It will be seen that one can write eigenvalue equations using an operator whose largest eigenvalue is $e^{-G(B)}$. (S34) The eigenfunctions are interesting, and their analysis will shed light on the free energy *G(B)* and on other eigenvalues in this formalism. *S35-S38 describe the scope of the theory.*

¶7 (S39) In Sec. II we derive the eigenvalue equations for complete trees. (S40) Section III discusses applications to dynamical systems. . . . (S41) In Sec. IV a detailed discussion of the singularities of the eigenfunctions is performed. *S42 discusses section IV*. (S43) Section V is devoted to the study of intermittent maps. . . . *S44-S45 discuss section V*. (S46) Section VI treats incomplete maps of the interval. . . . *S47-S50 discuss section VI*. (S51) Section VII is a summary and discussion.

APPENDIX C
Introductory Moves in Early-Y Article (Li & Yorke, 1975). E1 represents Exemplar Move 1.

Move E1: Raise a Common Situation or Example

¶1 (S1) 1. Introduction. The way phenomena or processes evolve or change in time is often described by differential equations or difference equations. (S2) One of the simplest mathematical situations occurs when the phenomenon can be described by a single number as, for example, when the number of children susceptible to some disease at the beginning of a school year can be estimated purely as a function of the number for the previous year. *S3 introduces Equation 1.1.* (S4) Of course such a model for the year by year progress of the disease would be very simplistic and would contain only a shadow of the more complicated phenomena. (S5) For other phenomena this model might be more accurate. (S6) This equation has been used successfully to model the distribution of points of impact on a spinning bit for oil well drilling, as mentioned in [8, 11], knowing this distribution is helpful in predicting uneven wear of the bit. (S7) For another example, if a population of insects has discrete generations, the size of the n + 1st generation will be a function of the nth. (S8) A reasonable model would then be a generalized logistic equation *[Equation 1.2]*. (S9) A related model for insect populations was discussed by Utida in [10]. (S10) See also Oster *et al* [14,15].

¶2 (S11) These models are highly simplified, yet even this apparently simple equation (1.2) may have surprisingly complicated dynamic behavior. (S12) See Figure 1.

Move 4a: Present Goal of New Work—General

¶2 (S13) We approach these equations with the viewpoint that irregularities and chaotic oscillations of complicated phenomena may sometimes be understood in terms of the simple model, even if that model is not sufficiently sophisticated to allow accurate numerical predictions.

Move 2: Review Previous Research

¶2 (S14) Lorenz [1-4] took this point of view in studying turbulent behavior in a fascinating series of papers. (S15) He showed that a certain complicated fluid flow could be modeled by such a sequence x, $F(x)$, $F^2(x)$ . . . which retained some of the chaotic aspects of the original flow. (S16) See Figure 2.

(continued)

APPENDIX C Continued

Move 3: Point to Gap

[Nothing applicable].

Move 4b: Present Goal of New Work—Specific

¶2 (S17) In this paper we analyze a situation in which the sequence $\{F^n(x)\}$ is non-periodic and might be called "chaotic." (S18) Theorem 1 shows that chaotic behavior for (1.1) will result in any situation in which a "population" of size x can grow for two or more successive generations and then having reached an unsustainable height, a population bust follows to the level of x or below. *[Note: Theorem 1 is presented in Section 2, which is headed "2. The main theorem."]*

¶3 (S19) In section 3 we give a well-known simple condition which guarantees that a periodic point is stable and then in section 4 we quote a result applicable when F is like the one in Figure 2. (S20) It implies. . . .

¶4 (S21) A number of questions remain unanswered. (S22) For example, is the closure of the periodic points an interval or at least a finite union of intervals? (S23) Other questions are mentioned later.

¶5 (S24) Added in proof. May has recently discovered other strong properties of these maps in his independent study of how the behavior changes as a parameter is varied [17].

APPENDIX D
Introductory Moves in Early-F Article (Feigenbaum, 1978).
E1 and E2 represent Exemplar Moves 1 and 2.

Move E1: Raise a Common Situation or Example

¶1 (S1) Recursion equations $x_{n+1} = f(x_n)$ provide a description for a variety of problems. (S2) For example, a numerical computation of a zero of $h(x)$ is obtained recursively according to *[unnumbered equation]. S3-S4 describe conditions on the equation.* (S5) In a natural context, a (possibly fictitious) discrete population satisfies the formula $p_{n+1} = f(p_n)$, determining the population at one time in terms of its previous value. (S6) We mention these two examples purely for illustrative purposes.

Move 4a: Present Goal of New Work—General

¶1 (S7) The results of this paper, of course, apply to any situation modeled by such a recursion equation. (S8) Nevertheless, we shall focus attention throughout this section on the population example, both for the intuitive appeal of so tangible a realization as well as for a definite viewpoint, rather different from the usual one toward this situation, that shall emerge in the discussion. (S9) It is to be emphasized, though, that our results are generally applicable.

Move E2: Present Original Background Material

¶2 (S10) If the population referred to is that of a dilute group of organisms, then *[Equation 1]. S11-S23 describe growth in a hypothetical population with 4 unnumbered equations, Equation 2, and Figure 1, leading to a generalized equation, Equation (3).* (S24) So long as *[certain conditions hold]*, relation (3) correctly (at least qualitatively) models the situation. (S25) However *[function 1]* affords an (a priori) equally good modeling as *[function 2]*. (S26) Thus only detailed quantitative results of (3) could determine which (if either) is empirically correct. (S27) One should then ask what the dynamical behavior of (3) is with f as in Fig. 1. (S28) It turns out that (3) enjoys a rich spectrum of excitations, with a universal behavior that would frustrate any attempt to discriminate among possible f's qualitatively. (S29) That is, providing (3) affords an honest model of a population's dynamics, so far as qualitative aspects are concerned, the data could not qualitatively determine any more specific form [such as (2), say]. (S30) Conversely, any such choice of f—say Eq. (2)—is fully sufficient for study to comprehend all qualitative aspects of the dynamics. (S31) If the data should in any way disagree qualitatively with the predictions of (2) then (3) for any believable f must be an incorrect model.

¶3 (S33) The qualitative information available pertaining to (3) for any f of the form considered . . . is quite specific and detailed. (S34) In discussing the numerical solution to $h(x) = 0$ a fixed point was considered. *S35-S51 discuss implications of the fixed point.*

¶4 (S52) With this terminology, some of the detailed qualitative features of (3) can be stated as follows. *S53-S63 describe general implications for population dynamics.* (S64) Thus, *[any observed deviation from certain parameters defined by (2)]* constitutes empirical proof that (3) for any believable f incorrectly models the population. (S65) On the other hand, if (3) is appropriate for some f, then (2) for all qualitative purposes, comprises the full theory of the population's evolution. (S66) The exact quantitative theory reduces to the problem of determining the particular f.

Move 3: Point to Gap

(S67) Unfortunately, even if (3) might be applicable, the data of biological populations are too crude at present to significantly discriminate among f's. ¶5 (S68) With so much specific qualitative information about (3) independent

(continued)

APPENDIX D Continued

of f available, we may ask if the form of (3) might not also imply some *quantitative* information independent of f.

Move 4b: Present Goal of New Work—Specific

¶5 (S69) It is the content of the following to answer this inquiry in the affirmative. *S70-S79 introduce alpha.*

(S81) In addition to alpha, another universal number determined by (3) should leave its mark on the data of a system described by (3). *S82-S83 introduce delta.* (S84) It must be stressed that the numbers alpha and delta are not determined by, say, the set of all derivatives of (an analytic) f at the same point. (S85) (Indeed, f need not be analytic.) (S86) Rather universal functions exist that describe the local structure of stability sets, and these functions obey functional equations [independent of the f of (3)] implicating alpha and delta in a fundamental way.

NOTES

1. Swales (1990) has combined Moves 1 and 2. We agree with this approach and the motivation behind it; Swales acknowledges that it was difficult to separate these moves systematically. However, the articles we treat tended to separate Moves 1 and 2 with a preview of Move 4. We therefore found the earlier (1984) formulation easier to apply to our texts.

2. Miller borrowed Stent's (1972) terminology in describing the work as "premature." Ideas are considered premature when their "implications cannot be connected by a series of simple logical steps to canonical or generally accepted knowledge [within the scientific community]" (p. 84).

3. Lorenz's work in 1963 and 1964, cited by Yorke (Li & Yorke, 1975), could more accurately be considered premature.

4. Interestingly, in "riper" situations, it even becomes possible to start the introduction with Move 3. Feigenbaum's (1979) sequel to Early-F, which provides the actual numbers to elaborate on the more theoretical Early-F, opens with the gap as does Watson and Crick's 1993 DNA article.

5. Charney (1993) uses a similar method to define hot spots, except that we included comments of all types rather than just evaluative reactions.

6. This is not to say that readers do not appreciate the presence of this information. One of the readers noted above, who skipped most of Move 2, commented approvingly on Feigenbaum's purpose in the open-ended interview: "Now Feigenbaum gives all the motivation for everything he ever did and in fact he sort of tells you how he got there by giving you his computational examples" (R10).

7. In general, our readers did pay attention to the appropriateness of cited references. Nine of the 12 readers turned to the references at least once; they commented on

whether the cited sources were familiar or checked to see if sources they thought should be cited were on the reference list. Two complained about the numerical citation system itself. One set himself the challenge of guessing which articles he would find in a citation before turning to the reference page.

8. Reprinted (abstracted) with permission from "Transitions to chaotic scattering." *Phys Rev A* Vol. 42, No. 12; 1 Dec 1990. Pgs. 7025-30 by Mingzhou Ding, Celso Grebogi, Edward Ott, and James A. York. Copyright 1990, The American Physical Society.

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REFERENCES

Baker, G., & Gollub, J. (1990). *Chaotic dynamics: An introduction.* Cambridge: Cambridge University Press.

Bazerman, C. (1988). *Shaping written knowledge: The genre and activity of the experimental article in science.* Madison: University of Wisconsin Press.

Blakeslee, A. (1993). Inventing scientific discourse: Dimensions of rhetorical knowledge in physics. (Doctoral dissertation, Carnegie Mellon University). *Dissertation Abstracts International, 53,* 2787A.

Charney, D. (1993). A study in rhetorical reading. In J. Selzer (Ed.), *Understanding scientific prose* (pp. 203-231). Madison: University of Wisconsin Press.

Dillon, A., Richardson, J., & McKnight, C. (1989). Human factors of journal usage and design of electronic texts. *Interacting With Computers, 1,* 183-189.

Ding, M., Grebogi, C., Ott, E., & Yorke, J. (1990). Transition to chaotic scattering. *Physical Review A, 42,* 7025-7040.

Feigenbaum, M. (1978). Quantitative universality for a class of nonlinear transformations. *Journal of Statistical Physics, 19,* 25-52.

Feigenbaum, M. (1979). The universal metric properties of nonlinear transformations. *Journal of Statistical Physics, 21,* 669-706.

Feigenbaum, M., Procaccia, I., & Tél, T. (1989). Scaling properties of multifractals as an eigenvalue problem. *Physical Review A, 39,* 5359-5372.

Gleick, J. (1987). *Chaos: Making a new science.* New York: Penguin.

Gragson, G., & Selzer, J. (1993). The reader in the text of "The Spandrels of San Marco." In J. Selzer (Ed.), *Understanding scientific prose* (pp. 180-202). Madison: University of Wisconsin Press.

Halloran, S. M. (1984). The birth of molecular biology: An essay in the rhetorical criticism of scientific discourse. *Rhetoric Review, 3,* 70-83.

Kaufer, D., & Carley, K. (1993). *Communication at a distance: The influence of print on sociocultural organization and change.* Hillsdale, NJ: Lawrence Erlbaum.

Keith, W., & Zagacki, K. (1992). Rhetoric and paradox in scientific revolutions. *Southern Communication Journal, 57,* 165-177.

Kuhn, T. (1970). *The structure of scientific revolutions* (2nd ed.). Chicago: University of Chicago Press.

Law, J., & Williams, R. J. (1982). Putting facts together: A study of scientific persuasion. *Social Studies of Science, 12,* 535-558.

Li, T., & Yorke, J. (1975). Period three implies chaos. *American Mathematical Monthly, 82,* 985-992.

May, R. (1976). Simple mathematical models with very complicated dynamics. *Nature, 261,* 459-467.

Miller, C. (1992). Kairos in the rhetoric of science. In S. Witte, N. Nakadate, & R. Cherry (Eds.), *A rhetoric of doing* (pp. 309-327). Carbondale: Southern Illinois University Press.

Myers, G. (1985). The social construction of two biologists' proposals. *Written Communication, 2,* 219-245.

Paul, D. (1991, July). *Introducing chaos: Article introduction as history.* Talk presented at the Penn State Conference on Rhetoric and Composition, University Park, PA.

Pinelli, T., Cordle, V., & Vondran, R. (1984). The function of report components in the screening and reading of technical reports. *Journal of Technical Writing and Communication, 14*(2), 87-94.

Prelli, L. (1989). *A rhetoric of science: Inventing scientific discourse.* Columbia: University of South Carolina Press.

Stent, G. (1972). Prematurity and uniqueness in scientific discovery. *Scientific American, 227,* 84-93.

Swales, J. (1984). Research into the structures of introductions to journal articles and its application to the teaching of academic writing. In R. Williams, J. Swales, & J. Kirkman (Eds.), *Common ground: Shared interests in English for special purposes and communication studies* (pp. 77-86). Oxford: Pergamon.

Swales, J. (1990). *Genre analysis: English in academic and research settings.* Cambridge: Cambridge University Press.

Swales, J., & Najjar, H. (1987). The writing of research article introductions. *Written Communication, 4,* 175-191.

Wyatt, D., Pressley, M., El-Dinary, P., Stein, S., Evans, P., & Brown, R. (1993). Comprehension strategies, worth and credibility monitoring, and evaluations: Cold and hot cognition when experts read professional articles that are important to them. *Learning and Individual Differences, 5,* 49-72.

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