

Complexity Science: A “Gray” Science for the “Stuff in Between”

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It is becoming rather monotonous continually reading articles that tell us how the concept of and the requirements for the modern organization are changing, how these are more complex than ever, and how a paradigm shift is necessary in order to facilitate our continued analysis, and management, of such entities. We are told that we must distribute decision making, encourage individual autonomy, and strive to innovate in the rapidly changing environment that characterizes the apparent New World Order. The list is as far reaching as it is impressive. These concepts coincide with a new, or at least emerging, description of organizations. This “paradigm” appears, from particular presentations at least, wholly to reject the long-held prevailing paradigm of the mechanistic, efficiency-driven, hierarchical, command-and-control organization. (We would question the “wholyness” of this position.)

Complexity science has emerged from the field of possible candidates as a prime contender for the top spot in the next era of management science. The number of management trade books on the subject has exploded, with provocative titles such as *Leading at the Edge of Chaos* (Conner, 1998), *ReWiring the Corporate Brain* (Zohar, 1997), and *Adaptive Enterprise* (Haeckel, 1999), to name but a few. The majority of the popular writings seem to claim that the “old” thinking is dead and needs to be (wholly) replaced with “new” thinking, and that a new, all-embracing perspective, sometimes referred to as “complexity thinking,” is available that will solve all our apparent woes. Of course, much of this is the hype that accompanies any “New Science,” and we should know by now that the inevitable disappointment is also not far away.

Despite the promise indicated by various authors within the field, complexity science has thus far failed to deliver tangible tools that might be utilized in the examination of complex systems. In an attempt to derive some *actionable knowledge* (Argyris, 1993) from the field, the aims of this article are briefly to familiarize the reader with the more popular aspects of complexity science, and then, by focusing on the issue of incompressibility, to provide a provisional outline epistemology that attempts to incorporate the lessons derived from computer-based observations of complex systems' behavior and mathematical analysis of simple nonlinear systems. It is difficult to provide a complete presentation within such a limited format and for the interested reader a much extended version of this article is available (Richardson *et al.*, 2000).

THE THEORY OF COMPLEXITY SCIENCE

WHAT IS A COMPLEX SYSTEM?

The general message from the popular complexity science literature seems to be that, where we once focused on the parts of a system and how they functioned, we must now focus on the interactions between these parts, and how these relationships determine the identity not only of the parts but of the whole system. Of course, as everything is connected to everything else, the notion of a distinct system as an entity becomes very blurred—where are the boundaries?

A complex (adaptive) system can be simply described as a system comprised of a large number of entities that display a high level of interactivity. The nature of this interactivity is mostly nonlinear, containing manifest feedback loops. It is interesting to note that a result of this is that sometimes it can be very difficult to associate effect with cause: Is the concept of the “learning organization,” so popular in current management streams, oxymoronic? At the single-loop level at least there is cause for concern. Nonlinear interconnectivity also places fundamental limitations on our ability to validate models of complex systems.

There are a number of basic observations that have been made through the examination of such systems, primarily through the use of computer simulation and the mathematics of nonlinearity. The following sections will discuss the nature and implication of these observations in turn. For a more complete list refer to Cilliers (1998).

- ◆ *System memory/history* (Cilliers, 1998: 4). A complex system has memory/history captured at both the micro- (e.g., personal experi-

ences, personal opinions, worldview) and macroscopic (e.g., culture, ritual, value system) levels. Therefore, system history plays an important role in defining the state of the system as well as affecting system evolution.

- ◆ *A diversity of behaviors* (Allen, 2001). A rich diversity of qualitatively different operating regimes exists that the system might adopt. This is a result of the nonlinear nature of the relationships that describe the interactivity between the different system constituents.
- ◆ *Chaos and self-organization* (Auyang, 1999). The system evolution is potentially incredibly sensitive to small disturbances (a phenomenon popularly referred to as deterministic chaos), as well as being potentially incredibly insensitive to large disturbances (as a result of self-organization or, alternatively, antichaos). All possibilities in between also exist. Complex systems are often quite robust.
- ◆ *The incompressibility of complex systems* (Cilliers, 1998: 4). Complex systems are incompressible, that is, it is impossible to have an account of a complex system that is less complex than the system itself without losing some of its aspects. Incompressibility (resulting from non-linearity) is probably the single most important aspect of complex systems when considering the development of any analytical methodology, or epistemology, for coping with such systems. The following section will explore the ramifications of incompressibility in greater detail.

THE INCOMPRESSIBILITY OF COMPLEX SYSTEMS

As mentioned above, in a complex system everything is connected to everything else, whether directly or indirectly. The concept of “boundary” therefore becomes problematic. Just because an obvious physical boundary is judged to exist doesn’t mean that it should be immediately assumed that this is the correct boundary for sensemaking. And, just because particular boundary judgments were used in the past doesn’t mean that they are appropriate again, even if the two situations appear to be the same. In fact, it is asserted that the boundaries that decision makers infer around a system are more a feature of our need for a bounded description than a feature of the system itself (Cilliers, 1998: 4). Boundaries are often drawn where we want them, and this may not be the best for the job at hand. At a fundamental level, boundaries are inferred in order to allow us to begin to make sense of our surroundings. Hard, enduring boundaries do not exist in nature; all perceived boundaries are transient given a sufficiently broad timeframe. This does not mean that

making the assumption that such boundaries exist is an unacceptable approximation in a wide variety of situations. An important aspect of sensemaking, which is beyond the scope of the current discussion, is how both implicit and explicit assumptions create, or force, the boundary for analysis (see Richardson *et al.*, 2000). For now, we will limit our discussion to the paradox of incompressibility versus our human need for boundaries, or compressibility.

As already stated, complex systems are *incompressible*. What this means is that if a model of a complex system were to be constructed that captured all the possible behaviors contained (both current and subsequent) by the system being represented, then that model must be *at least* as complex as the system of interest. The reason for this is that there will always be something outside of the boundary (i.e., the boundary inferred by the model) that would affect the system's behavior in some way at some time.

Let us adopt a skeptical stance for a moment: Because complex systems are sensitive to small changes, or small errors in our assumptions—that is, a small misplacement of the model boundaries—the model might be wholly inappropriate for the decision that it supposedly supports. “Something is better than nothing” would therefore be a wholly misleading guideline to bandy around the analytical community. (“Take nothing for granted” is possibly more suitable.) To model a complex system accurately, we would have to model life, the universe, and everything. As sensemakers, we would have to take the first proposition of Wittgenstein's *Tractatus*, “The world is all that is the case” (Wittgenstein, 1997), completely literally. Acknowledging that there is only one complex system is important, however, since it forces the analyst to recognize the narrow scope and provisionality of their representations. Given that no hard, enduring boundaries exist in reality, the use of the term “system” can be misleading, as it suggests the existence of *completely* autonomous entities. Maybe we should rename complexity science the “science of partial complex systems.” This usage would make explicit the fact that when considering any problem we are in fact investigating a *part* of a complex system. As such, all the hypotheses and concerns raised by a “science of partial complex systems” would be appropriate for all analyses, rather than just special cases.

Assuming the notion of incompressibility to be correct, what does this mean for analysis?

Incompressibility essentially negates the possibility of the existence of a globally and permanently valid perspective, or paradigm. Furthermore,

it means that there cannot be a perspective, paradigm, framework, etc. that can be used to wholly describe any subsystem embedded within *the* complex system. (Note that how we define any “subsystem” will be dependent on our perceptions and the use of our description rather than a permanent feature of the real world.) This observation may seem to deny the usefulness of sensemaking altogether. What it means, however, is not that we should not attempt to make sense, but that we should be strongly aware of, and blatantly open about, the provisionality of any perspective that might be utilized in underpinning an analysis of any problem—we must demonstrate considerable humility. Without this scientific “humility,” we will continue to believe that our current understanding is true and defines all that is possible (and desirable).

The skeptical interpretation of the implications of incompressibility does not offer much in the way of advice, or *actionable knowledge* for analysts. It essentially argues for a “paradigm-less” approach toward analysis in which categorization of any sort must be avoided: a plainly impractical and absurd argument, particularly given the category-based functioning of the human mind. Whether skeptics like it or not, we rely heavily on categorization to make sense of the world and to legitimate our decisions and resulting actions. The skeptical interpretation is best seen as a very important and profound health warning.

LOCAL VS. NON-LOCAL KNOWLEDGE

Consideration of incompressibility leads neatly into the debate over whether nonlocally valid descriptions of systems, that is, descriptions that are valid over a broad range of different contexts, are possible or whether we must accept the overwhelming context dependence of any description. (The reader should note that “local” should not be understood in the purely spatial sense. A certain factor may be “far away,” but if the *information* is available locally, it is local.) As has been indicated by most of the discussion thus far, there is no black-and-white answer, which in itself indicates that context is critical. Using the concepts of the phase portrait and the attractor basin helps us understand this question.

Let us assume that we have developed a model in which we have strong confidence, as it appears to account for much of the (partial complex) system’s currently observed behavior. The question arises as to whether we can now take this model and make predictions about the future operation of the system. The answer, from a complex systems perspective, is that if the qualitative nature of the assumptions that describe the new context remain valid, then the model will be useful, that is, if we

remain in the same attractor basin within the “assumption space,” then the knowledge derived from such a model can be straightforwardly translated into the new context. Qualitative changes in context prevent such a translation from occurring. So, at first consideration it seems that knowledge is strongly context dependent, but this dependence does not necessarily devalue this knowledge in light of a new context. Playing the skeptic again, the recognition that a new context is qualitatively similar to another is strongly subjective, and so some feature might be overlooked, however small, that would lead to the two contexts not being reducible to each other. There is considerable background “noise” in making such a judgment and, according to the phase picture, the impact of this noise depends on whether a separatrix has been crossed.

The essential lessons from this discussion on incompressibility are again diffused across a continuum. At worst, knowledge is so incredibly context specific that the search for understanding that is valid in other contexts is utterly futile; this has led to calls announcing the death of the expert (Taket & White, 1994). Consequently, attempts to make use of such knowledge in different contexts would be completely irresponsible, leading to wholly inappropriate advice and action. At best, knowledge based on a particular context is indeed valid for a bounded range of other contexts, but this validity should never be taken for granted; suggesting that the expert isn’t quite dead yet (Richardson & Tait, 2001). The quest for frameworks that attempt to describe the many contexts of complexity is not futile, but any frameworks developed should be regarded with a healthy skepticism when it comes to making use of them in specific circumstances. As an example, to characterize “wholes” within the complexity field itself consider the following.

The London School of Economics has a “complexity project” that is developing a complexity lexicon. The project researchers are encouraging the use of this lexicon when considering complexity. This might be considered a worthy aim by definition-minded modernists, but it must be remembered that there are an infinite number of ways to talk about complexity, and that the words used have different associations when used in different contexts—the transference of meaning is strongly context dependent. The meanings of words should not be defined and enforced at the global level, but should be allowed to be intersubjectively negotiated (Mingers, 1995) at the local level, through, say, critical dialog (Robinson, 1993). The prescribed lexicon will undoubtedly provide a sound starting point, but we should be overtly aware of how language, which is based in a particular perspective, limits our “vision.” Again, to

some this awareness may seem to be a trivial matter, but we believe it to be crucial, assuming that the world is complex and that the need for quasi-“paradigmless,” or multi-perspective, thinking follows naturally from this.

This much is certain: the quest for comprehensiveness ... is not realizable. If we assume that it is realizable, the critical idea underlying the quest will be perverted into its opposite, i.e., into a false pretension to superior knowledge and understanding. (Ulrich, 1993)

In many ways, complexity science provides insights concerning analysis that might be seen as nothing more than common sense. The need for an awareness of the provisionality of all understanding may seem obvious but, as a community, we seem to have forced this and other issues into the background. Maybe this is because we feel so much securer with the prevailing modernist view of Absoluteness and Truth: It's so much neater.

COMPLEXITY THINKING AS EPISTEMOLOGY

The aim of this article is not to question the basic observations made concerning “the complex system,” but to understand how the implications of these observations affect analysts' abilities to discover “truths” (with a small *t*) concerning such systems. Elsewhere (Richardson *et al.*, 2000) we have also suggested, in attempting to follow through these implications, that chunking the area of analysis into distinct “paradigms” is misleading, our insinuation being that complexity thinking leads to a break from traditional paradigm-based thinking, and the necessary destruction, or at least “fuzzification,” of the boundaries that allow us to recognize a paradigm as a paradigm. As a result, attempts to rigidly define the boundaries of the complexity paradigm are, we argue, contradictory to the fundamental complexity message. This does not mean that attempts to do so are not valuable, but it does mean that the boundaries should be seen as provisional and definitely local. We must each play the skeptic until such a time that we need to “fake” being “positivist” so that action can be justified and initiated. But, in so doing, and in recognition also of the fact that the system evolves, we need to review and possibly change the sense-making boundaries.

In the previous section the implications of incompressibility on analysis were explicated. In this section, we offer a high-level conceptual approach to analysis that acknowledges the difficulties previously discussed.

Given that no one perspective can capture the inherent intricacies of complex systems, the analysis of complex systems requires us to consider a number of perspectives. The underlying premise for this is that by exploring a number of perspectives, a richer appreciation of the “state of affairs” or “problematic situation” of interest will be developed, resulting in more informed decision making. In considering a variety of perspectives, a negotiation between these perspectives is encouraged that drives the exploration process. The merits and deficiencies of each perspective would be examined in light of both the supporting and contradictory evidence offered by the other perspectives. This evidence may be in the form of individuals’ experiences, the numerical output of a particular computer model, etc. As the different perspectives are played against and with each other, new perspectives emerge that are, at least, an eclectic mixture of the parts of the constituent perspectives that seem most relevant to the state of affairs under consideration. This intra- and interperspective exploration, or boundary critique, will identify other perspectives that might be worthy of inclusion, further fueling the exploration process. After a number of exploration cycles, perspectives that are deemed acceptable are left. This end point might come about in a number of ways: the creativity, fueled by the differences between the various perspectives or a variety of creative thinking exercises, may die out; the perspectives might naturally converge in a way that satisfies the basic needs of each perspective; or, a particular perspective becomes dominant and forces an end to the exploration process. Remember that in using the term “perspective” we are not distinguishing between formal and informal models, and so the perspective of the person who controls the budgetary strings also vies for a position in this interperspective exploration. The end point of an analysis then becomes the point at which a perspective, which may have emerged during the analysis or was present at the beginning, becomes overwhelmingly dominant.

In short, a principal requirement of a complexity-based epistemology is the exploration of perspectives. It may be useful to associate the terms *weak* and *strong* exploration, where weak refers to intraperspective exploration and strong refers to interperspective exploration. Weak exploration encourages the critical examination of a particular perspective, which is undoubtedly driven by its differences with other perspectives. Strong exploration encourages the sucking in of all available perspectives in the considered development or synthesis of a situation-specific perspective. These two types of exploration are not orthogonal, and cannot operate in isolation from one another. The greater the number of per-

spectives available, the more in depth the scrutiny of each individual perspective will be. The deeper or broader the scrutiny, the higher the possibilities are of recognizing the value, or not, of other perspectives. Essentially, complexity-based analysis is a move from the contemporary authoritarian or imperialist (Flood, 1989) style, in which a dominant perspective bounds the analysis, to a more democratic style that acknowledges the “rights” and value of a range of perspectives, whether they be formal modeling methods or informal and (inter)subjective personal viewpoints. The decision as to what perspective to use is also deferred until after the exploration process. While skepticism plays a central role in the exploration process, it plays a lesser role during implementation, at least initially. In order to implement a decision confidently, we must learn to fake positivism (something that comes quite naturally to most people), but always be aware that conditions will change and might require substantial rethinking of the implementation design itself.

The basic concept of strong and weak exploration is all well and good, but decision makers would be frozen by the plethora of possibilities that such paradigmatic freedom offers—the familiar *paralysis by analysis*. How would such an approach be operationalized? It is clear that the manager must, in addition to other activities, be concerned with the management of the variety of perspectives; an activity that falls under the umbrella term of *facilitation*. What other frameworks, however limiting, might support such a perspective-based dialog and negotiation?

OPERATIONALIZATIONS OF A COMPLEXITY-BASED EPISTEMOLOGY

Thus far, the article has discussed the epistemological implications of assuming that the world is best described as a complex system. Exploration both within and without different perspectives is encouraged, supporting the need for criticism, creativity, and pluralism. From a skeptical point of view, any attempt to operationalize such a complexity-based epistemology, via a well-defined framework, would be in contradiction to the underlying tenets. From a pragmatic point of view, however, we must accept that frameworks are essential in providing at least a focus or starting point for analysis. What we must be strongly aware of is that the theoretical insights offered by any framework should not be used to *determine* our explorations, but considered as an offering of *direction*, or simply as a source of creativity to fuel the exploration process.

A number of well-thought-out attempts have been made in the development of “meta-frameworks” that recognize the problematic nature of

sensemaking, offering guidelines as to how to manage the exploration process. These meta-methodologies have not been developed within the “official” complex systems research community, but within the management science community; more specifically, the operational research community. Examples of these developments include: the system of systems methodologies (Jackson, 1987); total systems intervention (Flood, 1995; Flood & Jackson, 1991); creative design of methods (Midgley 1990); and critical appreciation (Gregory, 1992). In order to legitimate the various methodologies a variety of philosophies are drawn on, such as Habermas’s early work on knowledge-constitutive interests as well as his later work on truth statements, rightness statements, and individuals’ subjectivity, Foucault’s theory of power, etc. For a good survey of the different methodologies and their associated philosophical underpinnings, see Midgley (1997).

On examining these different approaches, the reader may notice that generally each subsequent methodology attempts to make more explicit the role of ongoing critical reflection and the categorization process—partly driven by the ongoing critique of the different methodologies. In an extended version of this article (Richardson *et al.*, 2000), while acknowledging the coercive institutional forces (from regulative, normative, and mimetic pressures) acting to shape the form of any intervention, we discuss the culture in which any analysis is performed. We believe that if managers and scientists alike were to acknowledge the central role that critical thinking plays, there would be little need explicitly to design in the activity. After all, hasn’t examination of the underlying assumptions of any perspective always been associated with “good” analysis? If anything should be taken for granted it is the centrality of critical reflection, or boundary exploration and critique, to all forms of analysis. It is perhaps a poor reflection on the current analytical culture that critical thinking as an activity has to be made explicit.

SUMMARY AND CONCLUSIONS

A MODERNIST ARGUMENT FOR AFFIRMATIVE POSTMODERNISM?

By assuming the universe to be a complex system, complexity science offers an alternative perspective that supports the need for criticism, creativity, and pluralism through the notion of strong and weak exploration. It can be interpreted in such a way as to highlight the dangers of *any* categorization, via the concept of chaos, but also via incompressibility (by its acceptance of the need for categorization to “see” in the absence of a

complete representation of everything). By illustrating the inherently problematic nature of boundary selection, complexity science warns of the risks of employing off-the-shelf perspectives, and the need to partake in an intra- and interparadigmatic negotiation to facilitate the development of shared (by those having a vested interest in the outcome), context-specific representations of perceived reality. In a way, dare we suggest it, complexity science provides a modernist argument for affirmative postmodernism. Boundaries are constructed for convenience. Quasi-paradigmless thinking should prevail until we are forced to take a position, that is, fake positivism and temporarily invoke an imperialist stance.

All contexts are unique. If they were not, then past experience would always be sufficient when confronting any situation. This uniqueness means that attempts to associate existing understanding with particular contexts is problematic. However, we need also to acknowledge that the recognition of contexts is not a black-and-white, that is, trivial, exercise. Complexity science suggests that all our contexts should be considered “gray.” As such, new perspectives must be tailored to “fit” the new context (definition of which is problematic in itself) through the synthesis of a variety of formal and informal paradigms (used in the term’s broadest sense) via strong and weak exploration. Furthermore, complexity science (or “the science of partial complex systems”) warns us of attempts to systematize the exploration process, but, at the same, acknowledges such a requirement. A healthy skepticism must prevail to prevent us from slipping into potentially “bad” habits.

TAKING RESPONSIBILITY

One more point before we conclude. Complexity science raises some ethical concerns that refer to the inevitability of choices that cannot be backed up scientifically or objectively (Cilliers, 2000). Why associate these concerns with ethics? First, because the nature of the system or organization in question is determined by the collection of choices made in it. There are, of course, choices to be made on all scales, major ones as well as all the seemingly insignificant small ones made all the time—and remember that the scale of the effect is not necessarily related to the scale of the cause. In a way, the history of the organization is nothing else but the collection of all these decisions. Secondly, since there appears to be no final objective or calculable ground for our decisions, we cannot shift the responsibility for the decision on to something else: “Don’t blame me, the genetic algorithm said we should sell!” We *know* that all our choices

to some extent incorporate a step in the dark, and therefore we cannot but be responsible for them. This may have a pessimistic ring to it, but that need not be the case. An awareness of the contingency and provisionality of things is far better than a false sense of security.

In conclusion, we find that complexity science offers an alternative way of legitimizing the current interest in boundary critique, creativity, and pluralism. Furthermore, in acknowledging the partiality and provisionality of any attempt to describe a particular “problematic situation,” complexity science also raises concerns for how we recognize ethical behavior.

NOTE

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