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COMPLEXITY AND OPPORTUNITY IN SCIENCE COMMUNICATION

ABSTRACT

Science communication is resurgent at this time, early in the 21st century, when signs abound of a return to Enlightenment and a change in structures of knowledge comparable to the 17th transition from feudalism to the early modern period. Fears that a return to Enlightenment renders critical theory and cultural studies irrelevant may be unfounded. Science today is not defined by the Newtonian physics up until the 1950s, but by complexity. Unlike earlier models of transmission that defined communication research into the 1960s, complexity theory in science makes a dialogue or interactive model so much more necessary. Complexity is infused into science communication, which as a hybrid field draws from many different disciplines external to its own cluster of subjects, and internally from different aspects of that cluster. The obvious subjects include mass communication, media studies, communication theory and new media studies.

INTRODUCTION

Enlightenment is back, though it is too soon to tell what, if any, change it might have suffered during the *longue durée* of the recent counter-Enlightenment period well known for its postmodern rejection of rationalism, and the "science wars". Nonetheless, "[a]s a designation of period, as an intellectual clustering, as a method of experimental inquiry, and as an ideal, even, of rationality and toleration to be pitted against the world's zones of intolerance, it is back in circulation and generating new historical work" (O'Brien 2010: 1426). The return to rationality (that theoretical, scientific and deductive aspect of reason distinct from the narrative, rhetorical, the historically situated form of reasonableness) is not only in the discipline of history (see Toulmin 2001).

A wider transformation of "structures of knowledge" is taking place between the sciences, social sciences and humanities (Lee 1996; Lee & Wallerstein 2000). The term "structures of knowledge" refers to "those patterns of what can and cannot be thought that determine what actions can and cannot be deemed feasible in the material world" (Lee 2006: 116). (Whether or not Lee's definition resembles Foucault's

proposition of "discursive formations" need not concern us here.) In an article that reflects partly on the evident decline of cultural studies, Lee (2007: 11) sheds light on what the structures at play today imply:

> The categories through which we make sense of the world we live in, the groundings that give authority to explanatory frameworks, the rationales for the organisation of intellectual disciplines and university departments; all are undergoing a transformation. Furthermore, this upheaval is part and parcel of the exhaustion of the long-term processes reproducing the whole ensemble of the structures of the modern world.

Signs of this upheaval are evident in the academy, not least in the re-enchantment of science and the crisis in the humanities – both of which have been a feature for a few decades (Griffin 1988; Hall 1990; Pan 1998). Within this condition early in the 21st century, the communication field is flourishing when many of its longer-standing but less diverse peers in the humanities and social sciences are stagnant or in decline. The field of communication now finds itself in a position that is both enviable and fortunate, and one ought to consider whether the "restoration of Enlightenment" (if indeed that is an appropriate label for the return of modernity from its expressivist to its rationalist tradition) has anything to do with it.

This article assumes that the field of communication's (including journalism and media studies) improved standing in the academy has been assisted by historical factors to do with the transformation of knowledge structures; that communication as a discipline finds itself in the right place at the right time. This is not intended as a backhanded criticism. The sciences, too, are carried along in that favourable current. Include among the beneficiaries subjects and disciplines to do with business, management and medicine among others that self-identify in the turn to technology and practice (an empirical turn). But it is the emergence of one subject in the field of communication that is particularly significant, if the epistemic conditions assumed to exist are extant. The recent introduction of *science communication* to the bouquet of subjects offered as part of the field of communication may well be an epochal phenomenon made all the more feasible by a return to Enlightenment in this age of transition post-1990. Science communication's emergence takes advantage not only of a tendency towards specialisation and practice in communication curricula, but also an increasing attention to communication in professional education and training. Among these professionals are scientists themselves; but the perhaps the real impetus for science communication is the valorisation of the sciences.

The term "science communication" has traditionally referred to public exhibitions of new technology, to the professional practices of journalism and the publishing of popular science books and magazines, and to public relations to promote or to explain science to various audiences or publics. Beginning in about the mid-1800s, science communication developed from the exposition of science to include various forms of popular science writing by the later 1800s, and then to include the promotion of scientific knowledge through the nascent practice of public relations after the 1920s. It is informal, hence it differs from "science education" intended for audiences in formal educational institutions. Science communication, on the other hand,

brings knowledge of science … to citizens and consumers making decisions in today's societies, societies generally characterised by dependence on advanced scientific and technological developments for their food supplies, economies, built environments, transportation systems, medical care, and general health and welfare (Priest 2010).

More recently, particularly from the 1990s onward, the term science communication has come to refer to an interdisciplinary field of study situated within the field of communication. It is typically social scientifically oriented, and therefore is expected to systematically gather empirical (qualitative or quantitative) data, to use survey methods, as well as to use ethnographic methods to analyse cultural content and other observations. But the subject's breadth does not (indeed, cannot) remain so narrowly confined. It must learn from the experience of the humanities as much as it draws on the subject matter of the sciences. The fact/value distinction no longer prevails (at least not as intensely as before). As Priest (2010) puts it:

Science communication in the more academic sense of a field of social or behavioural science involves attempts to understand, influence, improve, and critique these processes, including attempts to grasp their broader social, political, and philosophical significance and dynamics, alongside their immediate impact on individuals and groups.

The relation of science communication to the knowledge of its parent body also needs to be considered. It would be a mistake to allow or even intend science communication to reconfigure the communication field or "megadiscipline" itself – to adopt a "science or nothing" stance, and to ignore the rich legacy of communication research steeped in the social sciences and humanities. Some systemic recalibration may well occur, as happened when cultural studies "structured the way the identity of Communication Studies could be, and was, articulated" (Maras 1998: 198). Not that cultural studies emerged from this marriage without taking on the family resemblance of its partner (Grossberg 1993). A not dissimilar cross-fertilisation may occur with science communication if it inherits the mantle of cultural studies; and there are good reasons to expect it may, and to steer the field of communication away from cultural questions and toward the service of science. But that does not imply abandoning or weakening its roots in the social sciences and humanities.

Even if, in the near future, communication teaching and scholarship does appear to abandon the familiar *Verstehen/Erklären* separation notably articulated by Wilhelm Dilthey in the 1890s (Harrington 2000; 2001), Max Weber and R.G. Collingwood, and hence developed in the interpretive tradition (see Martin 1999), to become an under-labourer of the science establishment – a relationship Winch (1958: 3-7) vigorously rejected in the heady Wittgensteinian mood of the 1950s – the paradigm it would now encounter in the sciences will be found to be quite antithetical to the Balkanising, positivist super-discipline usually referred to (in pejorative undertones) as Newtonian "Natural Science". The movement from quantum mechanics (consolidating in the 1930s) to chaos and then to complexity theory in about the 1990s calls for a transdisciplinary form of inquiry that roams across the sciences, social sciences and humanities.

A transdisciplinary science communication may not be a choice. Just as cultural studies emerged out of the crisis of modernity – even the "end of modernity", in Toulmin's (2001) view – to articulate the problematic of its time, so too is science communication particularly committed to the problematic(s) of the current period. An argument to this effect is found in Lee's (2003) assessment of the historical conditions in the structures of knowledge that fomented and later undermined cultural studies. Lee's viewpoint subscribes to Immanuel Wallerstein's world-systems analysis (Wallerstein 1974; 2004), and with whom he collaborates in research that includes in its scope the Enlightenment separation of the three systems of the humanities, the social sciences and the sciences (Lee & Wallerstein 2004). Lee (2003: 197-205; 2006; 2007) is particularly persuasive in arguing that the repudiation of Newtonian science through the development of quantum, chaos and then complexity theory have brought the knowledge structures that constitute modernity to a stage where the three knowledge systems are drawing together.

The view of modernity that informs Lee's argument concurs broadly with both Toulmin's (1990) and Charles Taylor's (1989) conception of modernity as a contradiction between broadly alternating Enlightenment (rationalist) and Romantic (expressivist) traditions that emerged in the bifurcation of the medieval Thomistic tradition that occurred with the 17th century scientific revolution, and which continue to oscillate dialectically through the modernity they constitute (Lash 1999). Modernity began with the 17th century scientific revolution, and was supported philosophically by a bifurcation of faith and reason that was articulated in Thomistic or scholastic philosophy. Enlightened reason had no need of faith, and science became the new vehicle of human salvation. The effects of an unencumbered reason became plain to see in the horrors of the Industrial Revolution and then the French Revolution of the late 1700s.

Public intellectuals of the time turned away from rationality to a recovery of feeling, sensibility and idealism in what in retrospect became known as the Romantic anti-Enlightenment. That period went into decline from the middle to the later-1800s when there appeared a resurgence of science. Philosophically, that transition was from idealism to a return to realism – the dualistic and contradictory poles of modernity. Science communication from this period to the 1930s can be understood as the communication of science (Bucchi 2002: 107-109). After a period from the mid-1950s to the 1990s, when the Romantic tradition emerged dominant in aesthetic modernism and postmodernism, there has occurred a "return to realism" which possibly indicates a resurgent Enlightenment (Dreyfus & Taylor 2015; Lee 2007; Toulmin 2001).

A view of modernity as an alternating set of Enlightenment and Romantic (or expressivist) traditions provides a useful backdrop against which to consider the current salience of science communication, and the opportunities this together with complexity theory (from science) offer to other subjects in the communication megadiscipline. An implication is that if scholars in science communication – a "growing area of practice and research" (Burns *et al*. 2003: 183) – were to adopt a disciplinary approach (see Pitrelli 2010; Trench & Bucchi 2010; Gascoigne *et al*. 2010), their emerging field would probably run counter to the transdisciplinary imperative characteristic of complexity

theory that defines science today, and which brings it into dialogue with the social sciences and humanities more so than at any other time in modernity.

COMMUNICATION AND MODERNITY

Mapping the development of the communication field in relation to the recent *longue durée* of modernity shows three more or less distinct formations. The field emerged as disparate threads of speech (see Gehrke & Keith 2014), journalism (Zelizer 2009) and signals (e.g. Shannon 1948) between the two world wars and a decade or so beyond that period. Using a distinction between *communications* ("referring to the institutions and practices of recording and transmitting symbols") and *communication* (to do with an "ideal of community") (Peters 2012: 403), "speech" may be seen to represent communication, and "signals" represents communications. While Maras (1998: 199) points out that the field displays a tension between the two mediated and unmediated forms, journalism may possibly be taken to represent that tension more so than do the interpersonal "speech" and the technical "signals" sides of the field. These terms may apply as three categories under which can be listed the various subjects found in the field of communication, with journalism possibly being re-designated instead as "media"; and, for that matter, by referring to "signals" as information and communications technology (ICT). But why stop there? Should these categories not be relabelled the humanities, the social sciences and the science and technology divisions of the field of communication?

When these categories are mapped on a timeline of recent modern history – 1920 to the present – it reveals more than a mere taxonomy of the field of communication. Lasswell's (1958) review of the "emerging discipline" shows that the communication field was, until the late 1950s, barely a discipline in its own right, but mostly a topic in the established disciplines in the "three cultures": humanities, the social sciences and in science. Walter Lippmann (in social science) and John Dewey (in the humanities), from the turn of the 20th century into the 1920s, pursued questions of communication in the two antithetical traditions of modernity: Enlightenment and Expressivism. Lippmann was more a "man of his time" than was Dewey; nevertheless, while he "remained deeply committed to reason", he also "recognised the limits of the Enlightenment model of rational man" (Jansen 2008: 73). It is only to be expected that an anti-Enlightenment scholarship in the postmodern period would tend to have misread him, as Jansen contends (2008: 71-73).

A successive period spans roughly the period 1930 to the time of Lasswell's (1958) review of the discipline. Lipmann's science of public opinion was enthusiastically taken up; so much so that "[f]rom 1936 until the 'communication' field had substantially migrated to journalism schools by the early 1960s, public opinion (or survey) research was, indeed, hard to distinguish from 'communication' study" (Pooley 2008: 58). Part of that impetus lay in wartime and subsequent Cold War government-funded psychological warfare programmes at the Columbia University under Bernard Berolson and Elihu Katz, and at the University of Illinois at Urbana-Champaign where communication pioneers Lasswell, Lazarsfeld and Schramm made their mark (Simpson 1996). During the war and into the 1950s, the positivist influence of natural

science driven by the needs of the United States military was perennial in the nascent discipline, as illustrated by Pooley (2008: 55, 56):

> Federal money – from the military, CIA, and State Department, often in close co-ordination with foundations such as Carnegie and Ford – poured into these university-based research institutes, as Simpson meticulously documents. Throughout most of the 1950s, and with no public acknowledgment, government funds made up more than three-quarters of the annual budget at Lazarsfeld's Bureau, [Hadley] Cantril's Institute for International Social Research at Princeton, Ithiel de Sola Pool's Centre for International Studies at MIT, and similar research shops. … [A]fter the mid-1950s when the campaign for third world hearts and minds heated up, prominent published research was based on secret propaganda work that was repackaged as disinterested science.

Along with communication science came a mathematised worldview that predominated in the social sciences well into the late 1960s, and came increasingly under critical scrutiny thereafter. But the turn to language and culture in the 1960s, which undermined the hegemony of the quantifiable material explanations of positivism and behaviourism into the 1970s, eventually reached an apogee in postmodernism beginning in the 1980s. The mood that descended particularly upon the humanities then and into the 1990s was one of crisis, of depletion and an exhaustion of relevance. The social sciences were not immune. Scholars from both branches of knowledge gave to explaining their continued purpose and relevance in ways that their peers in the sciences would have found unthinkable.

The current period early in the 21st century is characterised by two shifts in the reorganisation of thought that are analogous to a geomagnetic reversal. One is a return to Enlightenment. The other, related to the first, is a change in the structures of knowledge comparable to the 17th century transition from feudalism to the early modern period. Now that the pendulum finds in its return path the master categories of *technology* and *practice*, the communication field finds itself both with opportunities barely imaginable during the age of analogue media, and with a disturbing sense of *deja vu*.

Studies in digital and social media are coming to terms with the ubiquity of information and communication technologies in the social fabric. Subject offerings in corporate, organisational and business communication that had a Cinderella status in the disciplinary bouquet some decades ago are revitalised and increasingly in demand. But none of these highlight the epistemic shift in the structures of knowledge characteristic of the modern world-system (Lee & Wallerstein 2000) from which their buoyancy accrues in quite the same way as the emergence of science communication.

SCIENCE OF COMPLEXITY

While the sense prevails that Enlightenment has returned, the knowledge structures currently extent are quite unlike the traditional natural scientific separation of fact from value found in the Newtonian worldview, in order to better serve an "unbridled" discovery of natural laws. Gone also is the "clockwork universe". Post-1990 science provides us with "alternative models of physical reality in the form of relationally

constituted self-organising [autopoetic] systems and fractal geometry, and alternative models of change and transition expressed in complexity theory and chaos theory" (Lee 2007: 234).

The genesis of complexity in science can be plotted back to the mid-1800s, in the more recent history of modern science, when a revolution of paradigmatic proportions began to undermine the hegemony of classical Newtonian physics (prevalent until the late 19th century). The emphasis in Newton's physics was on "equilibrium and certainty and defin[ed] causality as the consistent association of antecedent conditions and subsequent events amenable to experimental replication and hypothesis testing" (Lee 2006: 122). It was the cornerstone of the scientific method.

Scientific certainty began to be questioned after Poincaré's observations in the 1880s of relativity in the supposedly immutable laws of physics. Max Planck's introduction of concept of quanta (the discrete units by which energy can be absorbed in matter) in around 1900 set in train a wave of research for the next 50 years in understanding atomic structure. Werner Heisenberg's uncertainty principle famously represents the consolidation of quantum mechanics in the 1920s. As new fields founded in quantum theory emerged – notably nuclear physics – Albert Einstein (also of this period), among others, predicted that revolutionary quantum theory would itself be replaced by yet another development, in much the same way it had overturned Newton.

This phase led finally to chaos theory in mathematics that developed rapidly during the 1980s. As expected, there was more that quantum theory had and could account for. For instance, research found that physical behaviour could be predicted only to "a point in time", beyond which it became random and eventually difficult to predict accurately in the longer term. This condition of chaos does not imply an absence of order – deterministic laws do still apply – but instead indicates a systemic complexity about which it became clear there remained so much more to find out. Furthermore, the natural world began to resemble the social world.

While chaos theory presents an advance driven by scientific questions about various anomalies in physics, the applications beyond the realms of traditional science have been transdisciplinary. A key theme has been to understand phenomena in terms of their complexity. The prevalence of complexity theory (and the paradigm) in current scientific research necessarily calls for expertise to be not only drawn from the social sciences and humanities, but also that the sciences enter into collaboration with those knowledge clusters (Lee 2007). Complexity also has a diachronic reach, enriching its realist perspective with the very same postmodern outlook through which critical scholars engaged science in the science wars (Cilliers 1998). But that picture comes from a view of the science wars as one waged between hardened positions of science and anti-science, or of reason and culture. One of the ironies of that episode, however, as Fuller (2001) points out, is that the names attributed to the science side were trained in the social sciences, whereas their apparently anti-science critics all had their training in the sciences.

Complexity cannot be given a simple definition, as Cilliers admits (1998: 2). Nor is complexity theory a single and coherent body of thought, "but is constituted by

a range of different traditions and approaches" (*ibid*.). A comprehensive description of complexity is unnecessary here, and only a sketch of its most salient features is provided to serve the conclusion of this article.

Cilliers (1998: 2-7) presents a view of ten characteristics of complexity in science depicted in postmodern theory. Listing and discussing these would provide too much detail; instead we shall consider Lee's (2007: 13) definition in relation to his comparison of the two cultures of the predominantly nomothetic natural science and the ideographic humanities as these appeared before the late 1960s. The tenor of science was "universal, positivistic, objective, fact-based and fact-producing … engaged in explaining order in a world where the past determined a predictable future via universal laws" (*ibid*.). The humanities, by comparison, comprised of particularist, chaotic, "qualitative disciplines where scholars dealt with an unpredictable and relativistic world of free human beings" (*ibid*.). The social sciences during this period remains between the opposition between universal science and the particularistic humanities – between truth and values – "by expressing the Enlightenment ideal of endless progress in an ultimately law-like, and therefore predictable, world" (*ibid*.).

Certainly, the social sciences' commitment to a naturalistic worldview and natural science methodology has been a key feature of its critique, beginning with Winch's (1958) initial salvo and followed by the sustained researches of cultural studies. Before long the gap between it and the humanities narrowed to the point where they became all but indistinguishable. Meanwhile, complexity science had also been moving away from its Newtonian legacy. Lee (2007: 17 - italics added) explains how this is happening:

> [T]he concurrent emphasis in complexity studies on contingency, context-dependency, system creativity and multiple, overlapping temporal and spatial frameworks *bears striking resemblance to the concerns of social scientists*, and 'objectivity' associated with externalism is called seriously into question by the identification and study of the feedback mechanisms of complex systems, including historical social systems. It is not just that new models of complex systems are being made available to social scientists, or that developments across the structures of knowledge are having similar epistemological consequences, but rather that the ontology itself underpinning the claim to legitimacy of knowledge constructed on the 'scientific' model is undergoing a transformation.

SCIENCE COMMUNICATION

The practice of science communication – or popular science writing and public exhibitions – has a long history which begins with the publication of scientific information for public consumption in the late 1800s, leading to a specialised but relatively small news beat that has gone through periodic booms and busts in tandem with newsworthy events such as the 1957 Soviet launch of Sputnik and the subsequent space race. Presently the practice of science journalism is in decline in mainstream media due mainly to matters of media economics; and there are few good reasons to expect the online jungle to offer a more viable alternative. Journalism treats science, celebrity

and flower show events with the same criterion: they must be newsworthy. Any other criterion is advertising (Mooney & Kirshenbaum 2009).

The roots of a dedicated science communication begin in the post-World War Two period following a conviction at government levels in mainly the United States, the United Kingdom and the Soviet Union that science had not only an important public educational dimension (Gascoigne *et al*. 2010), but was also a matter of national security. The early years of the Cold War are a significant backdrop and stimulus to this awareness. In Stalinist Russia, for instance, the very fate of the Soviet system was seen to rest on science; and its own internal science wars in the 1940s and 1950s both hinged on the patronage of its dictator and shaped its global policy for some time (Pollock 2006). Both Britain and the United States were no less eager about promoting science to their own geopolitical ends (Bud & Gummett 1999; Wang 1999).

Bauer and Gregory (2007: 35) state that "[i]n terms of content, we find that the first expansion of the 1950s is dominated by astronomy, the beginning of the space race, and by nuclear power, both civil and military – all of which are government-funded, national programmes". However the context of this information dissemination did little to foster enthusiastic public support for scientific endeavour. The science establishment was concerned about anti-science sentiment, which was not insignificantly informed by public resistance to new technology that inspired more fear and awe. During this period environmental and anti-nuclear activism did little to help sell science to a public being told what to do in the event of a Cold War nuclear Armageddon (Bauer & Gregory 2007: 33-35). After the Berlin Wall was toppled, science communication took a turn away from an interest in public technologies to commercial and private ones such as bio- and medical-technologies. But a turn towards complexity is also evident, as Bauer and Gregory (2007: 35) point out:

> Space and nuclear issues were replaced first by environmental news, then by computers, then in the 1990s by biotechnology as the dominant techno-scientific theme of the mass media. Over this period the public space commanded by the physical sciences declined, while that of the bio-medical and social sciences increased.

The post-Cold War stimulus given to science communication is interesting for a number of reasons. Among the more obvious reasons is a perceived need to bridge the gap between the scientific establishment and a potentially better-informed audience in order to improve the penetration of scientific knowledge into popular discourse. The knowledge economy and the commercialisation of science make a critical public necessary (Bauer & Falade 2008). This essentially educative ambition goes beyond wanting to stir public awe of science in the manner of popular television programming. While there is much that entertainment media can do to raise public awareness of, for example, how man's footprint puts our fragile natural world at risk, or of how irresponsible sexual behaviour can be life threatening, the stakes of science knowledge are considerably higher than mere knowledge consumption. Public-professional partnerships in scientific expertise may well improve the production of that knowledge as well as have more tangible effects in public health, the uptake of

improved technologies in industrial and domestic environments, with the prospects of increasing demand for the scientific research that produces these from the outset.

A freshly invigorated science communication is emerging as what some of its most active advocates predict will become a field in its own right (Pitrelli 2010; Bucchi & Trench 2014; Trench & Bucchi 2010). Gone are the caricatures of desperate scientists failing to explain their wizardry to an uncomprehending laity. Instead, the emerging field displays a far stronger inter-disciplinary quality that has the potential to mobilise knowledge drawn from across the communication family of subjects, and to integrate these with the subject matter of science. Science communication *is* an inter-discipline; it breaches boundaries that have traditionally kept apart the "hard" sciences from the social sciences and humanities.

Science communication embraces an intersectionality (to borrow a concept used in feminist critical theory) of perspectives and subject matters. It embraces, on the one hand, an historically realist, Enlightenment worldview and, on the other hand, the amalgam of critical, culturalist, hermeneutic, postmodern and constructivist perspectives that collectively defined the social sciences and humanities in the second half of the 20th century. While the intersections between these knowledge clusters recognise that no single perspective "has all the answers", it is less that kind of "deficit" that provides science communication with its potential to knit together the range of research available under the umbrella of communication (Trench 2008). That potential comes from within science itself, particularly the science of complexity which, in the social sciences, is already evident in content analysis, text mining, and network analysis (Bellotti & Mora forthcoming; Erikson 2013; Gao *et al*. 2014; Xu *et al*. 2011), "yielding explanations for social phenomena in a wide variety of disciplines from psychology to economics" (Borgatti *et al*. 2009: 892).

An intersectional understanding of science communication departs from earlier conceptions of the practice as a public relations endeavour given to transmitting information in the service of scientific interests (Borchelt & Nielsen 2014). It departs also from early museological practices of presenting science as a spectacle before publics (Schiele 2014: 40-41). Both forms have their roots in a deficit understanding of publics and audiences "which attributes negative public attitudes towards science to a lack of scientific knowledge" (Kirby 2008: 41); a view that "ordinary folks ought to know better". Certainly public relations no longer subscribes to purely linear, one-way models of communication (Grunig & Hunt 1984; Grunig *et al*. 2002), and museology also "examines the nature of the communication established with the visitors in a context where they are now the central concern of museum institutions" (Schiele & Landry 2012: 53). In the terminology of communication theory, the transition is from transmission to dialogue.

The concept of dialogue is ubiquitous in communication scholarship, but excitement about the potential of the concept for creating and transforming organisations, institutions and social worlds has also been accompanied by vagueness of what the concept means (Gergen *et al.* 2004: 40). Salient concepts do not occur simultaneously across disciplines, but often emerge within one after it has been exhausted in another.

Dialogue is one such concept, which Peters (2012: 34) argues is a "bad model" in its idealised form in communication theory. There are important forms of culture that are neither mutual nor interactive. But while the concept of dialogue will potentially help lead to a revision of science communication theory and method, its own scholars can take advice from the experience of their colleagues elsewhere in the field of communication.

Public relations theory has been similarly infatuated with dialogue, extrapolating interpersonal communicative forms into institutional and organisational settings; and it would appear from Trench's (2008) chapter on models of science communication that its long association with public relations practice (in the science establishment) has contributed in its movement from information transmission to dialogue with publics. But this speculation is not offered as a criticism of either field; nor even to necessarily attribute the shift to dialogue to that relationship. The adoption of dialogue as an approach in science communication is driven mainly from its realisation within science, particularly the implications of complexity theory.

CONCLUSION

The field of communication has undergone significant readjustments in the 21st century; adjustments that have found a shift toward technologies and practices, and a cooling of the vitality found in cultural studies particularly in the 1970s and 1980s. Few in the field seem willing to admit to a "narrative of decline", and instead attribute its loss of vitality to its institutionalisation in the academy (Turner 2012: 85). Lash points instead to hegemonic and a post-hegemonic periods, roughly occurring either side of the 1990s watershed; or where cultural studies finds itself as "first-wave" and then "second-wave" formations. Hegemony crystallised cultural studies as a field, and if "the hegemonic order works through a cultural logic of reproduction", the post-hegemonic power, operating "through a cultural logic of invention, hence not of reproduction but of chronic production of economic, social and political relations" entails a shift from value to facticity (Lash 2007: 56, 73):

> I want to argue that that epoch is now beginning to draw to a close. I want to suggest that power now, instead, is largely post-hegemonic. I want to suggest that cultural studies should look perhaps mostly elsewhere for its core concepts. I should also like to propose what some of these alternative concepts might be. I believe that these are not only concepts but also are the way in which power is beginning to work in a post-hegemonic age (Lash 2007: 55).

The intricacies of Lash's argument need not concern us here, except his indication of the epistemic transformation of knowledge structures that ought to discourage scholars in the field of communication (and cultural studies) to assume a "business as usual" attitude. The communication field's subject bouquet has mutated; cultural studies too must mutate; it "must engage with the culture industries: with art, the media, architecture, design, information and communications technology, software and protocol design, and urbanism" (Lash 2007: 74).

However fears that the valorisation of science (indeed in conditions of a return to Enlightenment) renders critical theory and cultural studies irrelevant may be unfounded in the sciences of complexity. As Lee (2007) argues, just as cultural studies, from its very inception in the 1960s, "consciously challenged the validity of the separations of the disciplines of knowledge formation" (Lee 2007: 232), so too we find at the heart of complexity science an understanding that natural phenomena do not always behave according to immutable and reversible Newtonian principles.

At the same time as there appears as a reorientation of subjects across the field of communication, science (and technology) communication as a field of research has quietly taken its place in the communication bouquet under favourable historical conditions that include a current valorisation of science not seen since the 1960s, when research first showed interest in "the role played by the media in science coverage" (Pitrelli 2010), but worked in a public environment generally hostile to science. The science communication field can learn from its disciplinary peers as much as these can use its subject matter. The field already recognised its multi- and interdisciplinary character within communication studies.

Science communication encompasses variations of all of these, united more by its subject matter than its methodology. Many of us draw our ideas about research (and our tools for conducting it) from a wide palette of potential choices. Further, communication studies programmes (home base for most science communication scholars) may have one of several overarching emphases, from journalistic practice to public relations work on the professional side, and from interpersonal to mass communication research on the academic side (Priest 2010).

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