Complexity as a Paradigm for Social Sciences and Linguistics: Theoretical Basis and Perspectives

Gemma Bel-Enguix[1][a], Ángels Massip-Bonet[2][b] and Gerardo Sierra[1][c]
[1]*Instituto de Ingeniería, Universidad Nacional Autónoma de Mexico, Ciudad de Mexico, Mexico*
[2]*Departament de Llengua i Literatura Catalanes, Universitat de Barcelona, Barcelona, Catalunya, Spain*

Keywords: Complexity, Complex Systems, Scientific Paradigm, Quantitative and Qualitative Methods, Natural Language as a CAS.

Abstract: This article discusses the relevance and significance of the use of complexity as a scientific paradigm in social and human sciences, focusing on linguistics. For this, a review of the concept of paradigm is made, and its evolution in the last decades. In this framework, the controversy between quantitative and qualitative methods and their validity in the twentieth century is discussed. In this dichotomy, we claim that the theory of complexity is prepared to assume the use of the so-called Mixed Methods Research (MMR). The paper develops the impact of Complex Systems (CS) and Complex Adaptive systems (CAS) in science, as well as the epistemological and methodological implications this entails. Moreover, natural language is defined as a CAS. In general, the article defends the adoption of this paradigm in linguistics, both in synchronous and diachronic research, providing some examples of these new lines of study. In spite of the still emerging nature of some formulations, we envision a deep theoretical breakthrough in linguistics thanks to this interdisciplinary perspective.

1 INTRODUCTION

Tomas Kuhn published in the sixties his influential essay *The structure of scientific revolutions* (1962). In this book, the philosopher argues that the underlying mechanics of scientific revolutions is a paradigm shift, understanding paradigm as a set of circumstances and intellectual possibilities that favor a different way of seeing the world and the phenomena under investigation. This idea is somehow opposed to Popper's theory (Popper, 1962), that states that science advances by accumulation, through falsifiability, discarding laws that contradict experience.

The idea of paradigm established a new way of standing before the dogmas of knowledge, and encouraged reflection on the philosophy of science and scientific methodology. However, the definition of the concept is not easy, and Kuhn himself seems to have used it with about twenty different meanings (Masterman, 1970). Guba and Lincoln (1994) understand the term as a set of basic beliefs that have to do with the last and first principles, and that cannot be proven in a conventional sense of the word. Mertens (2005) thinks that it can be defined as a way of looking at the world, composed of certain guiding philosophical assumptions, direct thinking and action. Neuman (2006) refers to a paradigm as a general organizational framework for theory and research that includes basic assumptions, key issues, research quality models and methods of finding answers. Denzin and Lincoln (2005), meanwhile, describe a paradigm as a network that contains the epistemological, ontological and methodological premises of a researcher. It is understood, then, that all research is interpretive and is guided by a set of beliefs and feelings of a researcher about the world and how it should be understood and studied.

An issue that has involved some controversy regarding scientific paradigms is the theoretical debate on methodology. Some authors (Guba and Lincoln, 1988) wonder if each of the research paradigms necessarily implies research methodologies. That is, they wonder about how a paradigm is structured, what its components are. In this regard, Guba (1990) himself makes relevant contributions in subsequent years. In the aforementioned work, the characterizes the re-

[a] https://orcid.org/0000-0002-1411-5736
[b] https://orcid.org/0000-0001-6845-2407
[c] https://orcid.org/0000-0002-6724-1090

Bel-Enguix, G., Massip-Bonet, Á. and Sierra, G.
Complexity as a Paradigm for Social Sciences and Linguistics: Theoretical Basis and Perspectives.
DOI: 10.5220/0009579901360142
In *Proceedings of the 5th International Conference on Complexity, Future Information Systems and Risk (COMPLEXIS 2020)*, pages 136-142
ISBN: 978-989-758-427-5

search in relation to the positioning about three aspects: the ontological - what is the nature of reality or of the cognizable -, the epistemological - what is the nature of the relationship between the cognitive and the cognizable - and the methodological - how the cognitive should proceed to apprehend knowledge. According to this position, the methodological aspect is constituent of the paradigm.

One of the most controversial debates in the area of Social Sciences and Humanities has been the dichotomy quantitative/qualitative. From the perspective of Guba (1990), the use of quantitative or qualitative methods is necessarily determined by the philosophical and epistemological options in which the project is framed or the researcher militates.

In the last years of the 20th Century, and in the first decade of the new millennium, several research paradigms are coexisting. Guba (1990) noted that the traditional framework of science since the nineteenth century is positivism, although this has been completed (or replaced) in recent years by three alternative scientific trends: post-positivism, critical theory and constructivism. However, the arising of new perspectives has been beyond this paradigmatic substitution. The age of communication is also the age of the 'multi' as a transversal idea in every field of knowledge. Eclecticism and coexistence of different views of the world and science is one of the most prominent characteristics of the contemporary societies.

Among the main pivotal ideas that have arisen in science in the last twenty years, one of the most consolidated is that of complexity, that can be seen as a multidisciplinary platform with the capability of having an impact in every area of knowledge.

In the following, we explain the emergence and theoretical bases the paradigm (Section 2). In Section 3 the debate between quantitative and qualitative methods is introduced. We also provide some ideas on how these could be integrated in complexity. Section 4 deals with the consideration of natural language as complex system. Additionally, we give some examples of branches of linguistics that have adopted this perspective. Finally, Section 5 shows why we support this new scientific position to study natural language as well as social sciences.

2 COMPLEXITY AS A PARADIGM

The modern concept of complexity in science has its roots in the advances that occurred in the twentieth century in some pilot disciplines (Marcus, 1974), such as biology and physics. In addition, in the same period, the foundations of cybernetics (Wiener, 1990; Ashby, 1956) and systems theory (von Bertalanffy, 1968) were laid, two disciplines that can be considered transversal.

The contributions in these disciplines had an impact in social sciences in the seventies, when authors like Gregory Bateson (1972) and Edgar Morin Morin (1973) took the theories introduced by cybernetics and systems theory to the fields of philosophy and communication.

The term 'complex systems' arose in the late 70s from the systems theory, although it was not extended as a research area until the 90s, when the Santa Fe Institute[1] was created. In one of the first works on the topic, Vemuri (1978), attempted an extensional definition, based on characteristics: large number of components, dynamicity and emergency. Some years later Gell-Mann (1995) made a first step for considering complexity an interdisciplinary paradigm for the study of both, natural and artificial entities, by going deeper into the structure and working of those systems. His definition followed the same pattern that Vemuri's, highlighting the following common features: large number of components, interaction, self-organization, emergency, non-linear behavior and dependence on previous actions.

At the beginning of 21st century Bar-Yam (2002) defined complex systems as a new discipline that approaches *how parts of a system and their relationships give rise to the collective behaviors of the system, and how the system interrelates with its environment*. From this definition, a large number of complex systems can be perceived, both in the domain of social sciences, as in biology or physics. Societies, the brain with its neural connections, water, weather, swarms, the immune system... can be examples of this phenomenon. But also some artificial constructions, such as traffic, internet communications or the economic network. In theory, then, complex systems offer a clearly transversal scientific perspective, with a possibility of methodological exchange and multidisciplinarity. Complexity offers an epistemological framework for science in the information society, where interconnection is a key element, and all research areas influence each other.

In this new scientific scenario, contributions from different areas of knowledge converge: philosophy and complex thinking (Morin, 2008), physics (Bohm, 1980; Prigogine and Stengers, 1992), biology (Maturana and Varela, 2004), and ecology (Allen and Hoekstra, 1992).

It seems that complexity has all the ingredients to have been understood as a research paradigm in the

[1] https://www.santafe.edu/

Kuhn sense. It epistemologically fits to the view of seeing the world of the 21st century. In this vein, it can provide a transdisciplinary umbrella for many phenomena that today are not perceived as they were some years ago. It has the concepts, methods and objectives that can give unity to the research.

The development of this concept has also implied the emergence of some common transdisciplinary methods of research. One of the best examples is the theory of networks (Barabási and Albert, 1999; Solé, 2009), a crucial technique in this framework. This method is directly related to the two pilot sciences of complexity, physics and biology.

Two more methodological tools that complex systems have integrated are statistics and data science. Both disciplines are commonly used nowadays for analysis in both social and formal sciences.

The nature of the techniques adopted by complexity, chiefly taken from physics and statistics, could cause that it has mainly linked with what has been called, in social sciences, the quantitative paradigm. This has entailed the rejection of some researchers, that align themselves with the qualitative framework. In Section 3 the problem will be approached.

3 COMPLEXITY AND QUANTITATIVE RESEARCH

As seen in Section 1, some authors include the methodological option as a substantial part of the paradigms. This view is especially present in social sciences and linguistics. An extreme example is the case of Bryman (1990), who states that in sociology there are two main paradigms, which depend on the adoption of quantitative or qualitative methods in research.

The epistemological confrontation between the researchers according to the use of quantitative or qualitative research methods was very much alive during the 80s, and has been called "paradigm warfare". In this war, various theoretical positions can be found, the extremes of which are occupied by the 'purists', and the 'pragmatists', while the 'situationalists' are placed in an intermediate position.

The 'purists' argue that methods cannot be mixed, since they are immeasurable, in the sense that Khun associates with the paradigms. The defenders of this idea are, among other authors, Bryman (1990) and Smith (1998).

At the other extreme, the 'pragmatists' argue that the dichotomy between the quantitative and qualitative research is false, and advocate for the coordinated and efficient use of both approaches (Tashakkori and Teddlie (2010); Johnson and Onwuegbuzie (2004); Smith (2011).

The 'situationalists' are in the middle of these two positions, arguing that some methods can be used in specific situations. Ortí (1995) and Serrano et al. (2009), among other authors, support this perspective.

Non-purist positions find their philosophical justification in Guba and Lincoln (1994), who assume that the methodological option is not part of the paradigm, and therefore does not distort the set of fundamental beliefs of the system. To do this, they propose to make a distinction between paradigm, strategy, methodology and data analysis for research in social sciences, behavioral sciences and human sciences. From this perspective, quantitative or qualitative methods can fit into different perspectives, since method questions are not nuclear.

Note the evolution suffered between Guba (1990) and Guba and Lincoln (1994), that is somehow illustrative of the theoretical change that social sciences experimented in the eighties and nineties, and which also opens the door to end hostilities between quantitative and qualitative approaches.

3.1 Mixed Methods Research (MMR)

The paradigm war (Creswell, 2003), which began in the eighties and lasted for two decades, ended up in the early 21st century with what Tashakkori and Teddlie (2010) called the third methodological movement, and Mingers (2003) a ceasefire. Finally, the battle has completely ceased, giving rise to what Buchanan and Bryman (2007) has come to call the 'paradigmatic soup', which is characterized by total eclecticism.

The agreement to make use of the so-called 'Mixed Methods Research' (MMR), and sometimes 'multi-method' or 'integrated' research (Creswell, 2003), is very strong in the framework of science in general. In addition, many voices advocate the need to extend the mixed methodology to the social sciences and to all those disciplines that may have connections with them.

The first question posed about MMR is whether they are a distinctive methodology in itself, or a simple combination approaches. Dealing with this issue requires having for a sufficiently general definition, understanding which scientific consequences entails each position, and envisioning the new lines of research that can be opening in each case.

Among the different explanations on how MMR works, a general one is provided by Creswell and Plano Clark (2007) who state that MMR are the basis of a research design with philosophical assumptions

and methods of information acquisition. The philosophical principles guide the compilation and analysis of data, and the use of both, quantitative and qualitative methods, in a study or series of studies. Is this combined use what provides better perspectives of the problem.

4 NATURAL LANGUAGE AS A COMPLEX ENTITY

The inclusion of natural language among complex systems has its roots in Gell-Mann definitions of complex systems, seen above (Section 1).

The main features described by Gell-Mann (1995), were completed with the description of Complex Adaptive Systems (CAS), introduced by Holland (2006), that include the traits of evolution and adaptation to the context. From here, natural language has started being considered a CAS. One of the first descriptions of this can be found in the paper by Beckner et al. (2009), which highlights the following features of natural language that link it with CAS: a) multiple agents, b) adaptations (evolution), c) speaker's behaviours are result of the past ones, and have an impact in the future, d) the behaviour of the speakers is the result of competing factors, from own abilities to the society, and e) language has emerging structures. According to this features, natural language shares many areas of research and methodologies with other disciplines and, therefore, its inclusion in CAS seems clear.

However, although natural language complies all the features of CAS, this problem and perspective has been repeatedly avoided in linguistics throughout the twentieth century. For decades, researchers have been afraid of dealing with the issue, because it can convey ethnic discrimination or other problems beyond science. Only under the new comprehension of science the topic has started to be tackled. In this new framework, two main ways of dealing with complexity have arisen: differences between two languages, and differences between historical periods of the same language, this is, synchronous and diachronic complexity (Andrasson, 2014).

4.1 Types of Linguistic Complexity

Complexity, as conceived by Gell-Mann, (1995) quantifies the computability of the non-random system information, ie. the order introduced by rules, as the opposite of randomness and disorder: the more complex the rules, the longer the description of the regularities.

The treatment of complexity in living languages can consider all aspects of the system. In principle, synchrony and diachrony refer to two different approaches, typological and evolutionary.

A good introduction to typological complexity is given by Miestamo et al. (2008). In a chapter of this book, (Miestamo, 2008) the author distinguishes between absolute and relative complexity. The former is based on the number of parts of the system, and follows the idea that the more parts a system has, the more complex it is. Of course, the concept is not so simple, and could be expressed in number of interactions, saying that increasing the number of interactions between the components of a system increases the complexity (Fenk-Oczlon and Fenk, 2008). This approach has been developed, among others, by Dahl (2004). The latter is defined in terms of cost and difficulty to language users (Miestamo, 2008). This is, the more difficult a phenomenon is for the user, the more complex it is. The problem with this approach is that the difficulty is not always the same for all the users or groups, depending on the social stratum, education or dialect. Moreover, the different perspective between speaker and hearer has to be taken into account. Usually, what is easier for speaker is more difficult for hearer, and vice versa. Hawkins (2004) is one of the main authors in the area of relative complexity.

The typological complexity is eminently cross-lingual, because all comparisons must be established by comparison between languages. However, the evolutionary approach, is more related to the contrast between different stages of the same language.

In regards to the evolutionary approach, it assumes that there is no stable state, in terms of lexical units, sounds and grammatical rules. As settled in the main theory of CAS, a stage of the language is directly influenced by previous stages, and affects the configurations of the future. Kirby (2002) distinguished three main areas in language evolution: ontogeny (language learning), glossogeny (cultural evolution), and phylogeny (biological evolution). Among the authors that have adopted a diachronic perspective can be cited Narrog and Auwera (2011), Massip-Bonet (2013) and Mufwene (2013).

Croft (2000) took the methods of the theory of evolution to explain language change and death. Some authors that have dealt with the emergence of linguistic properties (Kirby and Hurford, 2002; Hutchins and Hazlehurst, 2002), the former from a clear darwinian perspective, the latter using the concept of auto-organization as the power that guides the evolution.

The method by excellence of complex approaches to language emergence and evolution is simulation

(Cangelosi and Parisi, 2002; Nettle, 1999; Kirby et al., 2014). This is because of the lack of data about the conditions and dynamics that caused the emergence and first stages of evolution of languages.

Both, the synchronous and the evolutionary state of the language, need the knowledge of other aspects which are mainly social, historical and cultural. This fact has boosted the development of other branches of linguistics form the perspective of complexity, like sociolinguistics (Mufwene, 2013; Bastardas-Boada, 2013), dialectology (Massip-Bonet, 2018b) and historical linguistics (Massip-Bonet, 2018a).

Languages are fundamentally dynamic phenomena. The causes of its change and evolution, as well as its state in a given time, are subject to different interdependent pressures. In general, to explain the processes that lead to the use or not of a language, or to do it in certain contexts, the simulation of ecosystems and adaptive systems is often used. Languages adapt to contexts and environments, and their uses and structures depend on a fragile balance, which is based on numerous vectors. All this network of interdependences has been treated by Bastardas-Boada (2013) and Ellis and Larsen-Freeman (2009), among others.

This ecological tension that models the dynamics of sociolinguistics has been described in Terborg (2006) and Terborg and Landa (2013). The authors introduce the 'Ecology of Pressure's as a complex theory that computes different pressures – brain/mind, habits of social behaviour, demo-social groupings, socioeconomic structure, the media and political power – that constantly interact to determine which is the force that prevails in our use of language in every situation.

5 CONCLUSIONS

In this paper we have considered complexity as a research paradigm, both for sciences and humanities. Emerging between the second and the third millennium, this framework has been involved in what can be called a methodological war, especially in social sciences. This implies a controversy between quantitative and qualitative methods, that cannot be avoided, taking into account that this research proposal takes the methods mainly from physics and mathematics, but is, par excellence, multidisciplinary and ready to develop MMR research designs.

For understanding why the concept complexity is so important for social sciences, it is necessary to understand how complex systems are defined, their features and commonalities. We highlight throughout the paper that natural language is a prototypical complex system. However, assuming this entails serious epistemological and methodological positions that are not always easy to hold and practice in the field of humanities.

Finally some examples of how complexity can be applied in very different manners to linguistics have been presented.

New paradigms like complexity have an impact in the view of the world, in theoretical and comprehensive approaches of knowledge and in the scientific methodology. In this latter aspect, new tools for apprehension and treatment of the data are necessary, that are able to make us understand the phenomena from a completely new perspective. Therefore, this could be a revolution in the treatment and interaction with (language) data. This opens a new way for a joint and unified explanation of complex phenomena that may appear in entities belonging to different sciences.

However, nowadays complexity is not ready to provide an integrated and unified corpus of theory that configures a unifying paradigm. It has to create yet an own terminology, language, methodology and the integrated interpretation that we claim is characteristic of it. Summing up, a theoretical framework for complex entities has to be built yet, capable to clarify the interpretation of science we propose and, moreover, establish the foundations of a paradigm that can be a very effective umbrella for several areas of research in the next decades.

REFERENCES

Allen, T. and Hoekstra, T. (1992). *Toward a Unified Ecology*. Columbia University Press, New York.

Andrasson, A. (2014). Language complexity: An insight from complex-system theory. *International Journal of Language and Linguistics*, 2(2):74–88.

Ashby, W. (1956). *An Introduction to Cybernetics*. Chapman & Hall, London.

Bar-Yam, Y. (2002). *Encyclopedia of Life Support Systems*, chapter General Features of Complex Systems.

Barabási, A.-L. and Albert, R. (1999). Emergence of scaling in random networks. *Science*, 285(15 October 1999):509–512.

Bastardas-Boada, A. (2013). *Sociolinguistics: Towards a Complex Ecological View*, pages 15–34. Springer, Berlin.

Bateson, G. (1972). *Steps to an Ecology of Mind*. Ballantine Books, New York.

Beckner, C., Blythe, R., Bybee, J., Christiansen, M., Croft, W., Ellis, N., Holland, J., Ke, J., Larsen-Freeman, D., and Shoeneman, T. (2009). Language is a complex adaptive system. *Language Learning*, 59(Suppl. 1, December 2009):1–26.

Bohm, D. (1980). *Wholeness and the Implicate Order*. Routledge & Kegan, London.

Bryman, A. (1990). *Quantity and Quality in Social Research*. Unwin Hyman, first ed. 1988 edition.

Buchanan, D. and Bryman, A. (2007). Contextualizing methods choice in organizational research. *Organizational Research Methods*, 10(3):483–501.

Cangelosi, A. and Parisi, D. (2002). *Computer Simulation: A New Scientific Approach to the Study of Language Evolution*, pages 3–28. Springer London, London.

Creswell, J. (2003). *Research design. Qualitative, quantitative and mixed methods approaches*. Sage, Thousand Oaks, CA, first edition 1994 edition.

Creswell, J. and Plano Clark, V. (2007). *Designing and conducting mixed methods research*. Sage, Thousand Oaks, CA.

Croft, W. (2000). *Explaining language change: An evolutionary approach*. Longman, London.

Dahl, O. (2004). *The Growth and Maintenance of Linguistic Complexity*. Number 71 in Studies in Language Companion Series. John Benjamins, Amsterdam.

Denzin, N. and Lincoln, I. (2005). *Handbook of Qualitative Research. Third Edition*, chapter Competing paradigms in qualitative research. Sage.

Ellis, N. and Larsen-Freeman, D. (2009). *Language as a Complex Adaptative System*. Blackwell Publishing, Oxford.

Fenk-Oczlon, G. and Fenk, A. (2008). *Language complexity: Typology, contact, change*, chapter Complexity trade-offs between the subsystems of language. John Benjamins.

Gell-Mann, M. (1995). What is complexity? *Complexity*, 1(1):16–19.

Guba, E. (1990). *The Paradigm Dialog*. SAGE Publications.

Guba, E. and Lincoln, Y. (1988). *Qualitative approaches to evaluation in education*, chapter Do inquiry paradigms imply inquiry methodologies?, pages 89–115.

Guba, E. and Lincoln, Y. (1994). *Handbook of Qualitative Research*, chapter Competing paradigms in qualitative research. Sage.

Hawkins, J. (2004). *Efficiency and Complexity in Grammars*. Oxford University Press, Oxford.

Holland, J. H. (2006). Studying complex adaptive systems. *Journal of Systems Science and Complexity*, 19(1):1–8.

Hutchins, E. and Hazlehurst, B. (2002). *Auto-organization and Emergence of Shared Language Structure*, pages 279–305. Springer London, London.

Johnson, R. and Onwuegbuzie, A. (2004). Mixed methods research: A research paradigm whose time has come. *Educational Researcher*, 33(7):14–26.

Kirby, S. (2002). Natural language from artificial life. *Artificial Life*, 8(2):185–215.

Kirby, S., Griffiths, T., and Smith, K. (2014). Iterated learning and the evolution of language. *Current Opinion in Neurobiology*, 28:108–114.

Kirby, S. and Hurford, J. R. (2002). *The Emergence of Linguistic Structure: An Overview of the Iterated Learning Model*, pages 121–147. Springer London, London.

Kuhn, T. (1962). *The Structure of Scientific Revolutions*. University of Chicago Press, Chicago, Il.

Marcus, S. (1974). *Linguistics as a pilot science*, pages 2871–2887. Mouton, The Hague.

Massip-Bonet, . (2013). *Complexity Perspectives on Language, Communication and Society*, chapter Languages as Complex Adaptive Systems: Towards an Integrative Linguistics, pages 35–60. Springer, Heidelberg.

Massip-Bonet, . (2018a). *Imbricacions entre variació històrica i variació geogràfica en la llengua catalana*. UBe Publicacions i Edicions de la Universitat de Barcelona, Barcelona.

Massip-Bonet, . (2018b). *Lèxic i semàntica dialectal: aproximació des de la complèxica*. UBe Publicacions i Edicions de la Universitat de Barcelona, Barcelona.

Masterman, M. (1970). *Criticism and the Growth of Knowledge*, chapter The Nature of a Paradigm, pages 59–89. Cambridge University Press, Cambridge, UK.

Maturana, H. and Varela, F. (2004). *De máquinas y seres vivos. Autopoiesis: la organización de lo vivo*. Lumen, Buenos Aires.

Mertens, D. (2005). *Research and Evaluation in Education and Psychology: Integrating diversity with quantitative, qualitative, and mixed methods*. Sage, Boston, Mass, 2nd edition.

Miestamo, M. (2008). *Language complexity: Typology, contact, change*, chapter Grammatical complexity in a cross-linguistic perspective. John Benjamins.

Miestamo, M., Sinnemäki, K., and Karlsson, F. (2008). *Language complexity: Typology, contact, change*. Number 94 in Studies in Language Companion Series. John Benjamins, Amsterdam.

Mingers, J. (2003). The paucity of multimethod research: a review of the information systems literature. *Information Systems Journa*, (13):233–249.

Morin, E. (1973). *Le paradigme perdu: la nature humaine*. Éditions du Seuil, Paris.

Morin, E. (2008). *La méthode*. Éditions du Seuil, Paris.

Mufwene, S. (2013). *Complexity Perspectives on Language, Communication and Society*, chapter The Emergence of Complexity in Language: An Evolutionary Perspective, pages 197–218. Springer, Heidelberg.

Narrog, H. and Auwera, J. v. d. (2011). *Complexity Perspectives on Language, Communication and Society*, chapter Grammaticalization and semantic maps, pages 318–327. Oxford University Press, Oxford.

Nettle, D. (1999). Using social impact theory to simulate language change. *Lingua*, 108(2–3):95–117.

Neuman, W. (2006). *Social Research Methods: Qualitative and quantitative approaches*. Pearson, Boston, Mass, 6th edition.

Ortí, A. (1995). *La confrontación de modelos y niveles epistemológicos en la génesis e historia de la investigación social*, pages 85–95. Síntesis, Madrid.

Popper, K. (1962). *Conjectures and Refutations: The Growth of Scientific Knowledge*. Routledge, edition 2002 edition.

Prigogine, I. and Stengers, I. (1992). *Entre le temps et l'éternité*. Flammarion, Paris.

Serrano, A., Blanco, F., Ligero, J., Alvira, F., Escobar, M., and Sáenz, A. (2009). La investigación multimétodo. Technical report, Avalilable at http://eprints.ucm.es/30034/1/araceli20serrano%20articulacion_metodologica._serrano_blanco_alvira.pdf.

Smith, J. (1998). *The Book*. The publishing company, London, 2nd edition.

Smith, J. (2011). Mixed methods research: The five ps framework. *The Electronic Journal of Business Research Methods*, 9(2):96–108.

Solé, R. (2009). *Redes complejas. Del genoma a Internet*. Tusquets, Barcelona.

Tashakkori, A. and Teddlie, C. (2010). *Handbook of Mixed Methods in Social & Behavioral Research*. Sage, California.

Terborg, R. (2006). La 'ecología de presiones' en el desplazamiento de las lenguas indígenas por el español. presentación de un modelo. *Forum: Qualitative Social Research*, 7(4).

Terborg, R. and Landa, L. G. (2013). *Sociolinguistics: Towards a Complex Ecological View*, pages 219–246. Springer, Berlin.

Vemuri, V. (1978). *Modeling of Complex Systems: An Introduction*. Academic Press, New York.

von Bertalanffy, L. (1968). *General Systems Theory: Foundations, Development, Applications*. George Braziller, New York.

Wiener, N. (1990). *Cybernetics or Control and Communication in the Animal and the Machine*. The MIT Press, Cambridge, Massachusetts.