Available online at eruditio.worldacademy.org
Eruditio
e-Journal of the World Academy of Art & Science
Volume 2 Issue 6, September 2020

Physics and Cognition

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Abstract

Every physical object, celestial body or a living being, is characterized by the emission of physical quantities (or "grandeurs") that we define as mass, energy, and "form" (physical order, or shape, or arrangement). The emission of form is usually called information. Mass and energy are physically equivalent. And energy is a conservative grandeur. On the other hand, form is perceived by an observer as "meaning". But meaning is non-conservative. Hence there is difficulty in proposing a physical theory of information. One of the basic nineteenth-century assumptions about knowledge was "determinism", i.e. the conservation of information in the evolution of physical systems. Modern science re-ordered reality through a search of invariances in natural phenomena that in turn corresponded to laws of nature. Its success in describing natural transformations supported and promoted a culture of separation of the basic components of daily life in every community (economy, society, culture, politics, ethics, state, religion…). The forces of finance and capital strived and prospered during the turbulences and changes, progresses and crises, of Western nations. However, the ends of the two most powerful physical theories today, General Relativity and Quantum Mechanics, do not meet at our scale. But everything seems connected. No longer can life be separated from the environment, nor can ontology be separated from epistemology. The attempts to describe reality seem hampered by the conspicuous absence of a conservative grandeur in the field of form. With such a concept, the measurement of the cognitive content of any society could become as dull and commonplace as the GDP.

1. The Rise of Intangible Investment: A New Paradigm

Whole industrial sectors based on information technologies have been created in the past few decades. The increasing importance of intangible or immaterial investment (R&D, software, education and training, organization, regulation, marketing, design) has shown that the nature of the basic processes of economic activity is being transformed. The reason being that an information transaction is not a pure "exchange" (e.g. as it happens for tangible things) but rather a "sharing" transaction.

The growing intensity of sharing transactions in a society reveals that the restrictions to the performance of modern economies reside essentially in the abilities of the operators themselves. Thus, endogenous (or accessible) knowledge potential, its form or organization, and the capacity to exploit it, are crucial elements of success and survival in the new economic environment. The effects of misunderstanding, of no apprehension of communicated information (which causes an inability to generate relevant meanings) can be devastating.

Two distinctive features characterize our times: the quantity of material change and the quantity of intangible activity.[1] They can be measured, respectively, by the rate of innovation and by the intensity of communication in our societies. Initially nurtured by (but also enhancing) globalisation mechanisms and procedures, innovation and communication stimulate modifications which display a plural conception of rationality, whose "plasticity" is well suggested through the nature and power of "sharing", the basic regulator of information transactions.

The perspective of rationality as a field crossed by processes of rationalization tries to respond to that plurality—which can be designated, inspired by the ideas of Wittgenstein, by "rationality games".[2] These processes are differentiated, heterogeneous, and conflictive, regulated by different matrices according to the fields of knowledge, the historical periods, or the research communities in which they emerge and develop.

The system of classification of knowledge we inherited from late positivism, a pyramid with science at the top, aimed not only at the consecration of science as the model of all other fields of knowledge but also at establishing a corresponding hierarchy, is no longer adequate. Novelty comes from the emergence of a new factor, the immaterial order, in the realm of a material paradigm of progress and prosperity.

Information and knowledge have to be subtracted from all the regimes of cumulative possession so well characterized by the empirical metaphor of the deposit. These regimes are substituted by the regimes of reception and audience. What this means is that knowledge can no longer be thought of as fluid, as in a mechanical framework, but has to be understood in terms of a new paradigm, enhancing its communicative, language-based features.

No classification of knowledge can be envisaged without a reference to the societal context in which it is generated. The present notion of "explosion" of information and of "fragmentation" of knowledge is probably the result of the powerful weakening and fragmenting effects that the forces of expanding markets provoke in the social order of our nations.

But this is not a singularity of our epoch.[3] Fragmentation of prevailing social order has been experienced intensively in the past.

2. A New Organization of Knowledge

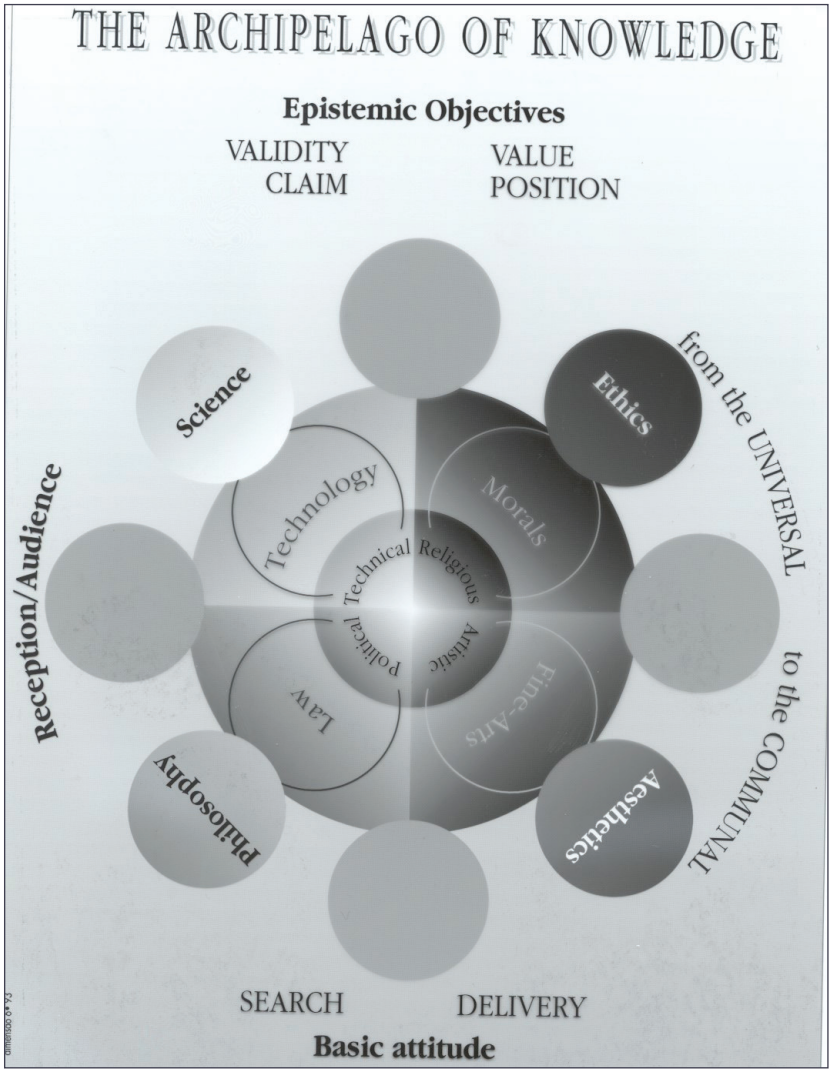
In medieval times, when the concept of central finite space prevailed (the Earth was seen as the center of the Universe), philosophy was posed at the center of knowledge, surrounded by the seven liberal arts: grammar, rhetoric, dialectic, music, arithmetic, geometry and astronomy. Later, with Enlightenment and the idea of the Encyclopedia, the strong and noble character of a highly advanced agricultural and commercial society envisaged knowledge as a tree, with the various fields developing as successive ramifications from a common stem: philosophy. Three main branches of the tree were assumed: the science of God, the science of Nature, and the science of Man.

In the 19th century, the success of the industrial society brought by the triumph of mechanics, railroads and iron, led to a new rationale, which culminated in the deployment of a new structure for knowledge classification, the positivist's pyramid, with mathematics and

the other (hard) sciences in a descending order from the top, presiding over philosophy, the humanities and religion.

This was the organization of knowledge which was conveyed and taught to us and which reigned undisputed until the 1960s. However, from the standpoint of contemporary society, it is certainly difficult to maintain rigid distinctions between different fields of knowledge. One can easily understand this by noting the proliferation of disciplines which has greatly intensified since the middle of the 20th century and the increasing internal complexity and autonomy of various disciplines.

Figure 1: The Archipelago of Knowledge (Source: Reference 3)



To try to think of contemporary fields of knowledge on the basis of their classical divisions and hierarchy obviously involves risks, especially the risk that important segments of contemporary knowledge which are sometimes more innovative may be left out despite, or perhaps because of, the fact they are unclassifiable in the light of current criteria.

The issue is simple: criteria do not have any meaning outside strategies. This fact, together with the sense of a lack of global or objective point of view—a "god's eye" which, it has to be remembered, has always been the classic ideal of philosophy and epistemology and also the argument that would allow to determine the place and status of other fields of knowledge—on one hand forbids one to speak of a system of fields of knowledge today, and on the other hand suggests a reappraisal rather than the dismissal of disciplinary references.

In this sense, the metaphor of an "archipelago of knowledge" may be useful and heuristically operative, particularly to the extent that it allows us to think, without any reductionism, of the articulation of criteria/strategies that guide the internal "thematization" of the main areas of relevance.[4]

In this perspective, "argumentativity" appears as a good criterion for the production of knowledge, thereby distinguishing science and philosophy from ethics and aesthetics; and the "audience" may be seen as another strong discriminating factor, from the point of view of knowledge reception, which distinguishes science and ethics from philosophy and aesthetics. Reception is supposed to be universal in the first case and communal in the second; this is undoubtedly a significant complementarity.

This approach leads to a new descriptive understanding of the realm of knowledge, as an archipelago, suggesting a reticular situation, i.e. a network, which does not postulate any common origin nor accept any "natural" or functional hierarchy. The loss of importance, if not of the aim itself, of arboreal or pyramidal conceptions of the fields of knowledge, is the most decisive effect of the emergence of the immaterial paradigm. Further, it is a scheme that allows and encompasses the creation of new disciplines.

To understand some of the main consequences of the proposed image of the contemporary situation in the fields of knowledge, it would be useful to remember that the traditional approach to science and knowledge has involved the use of two perspectives—an epistemological one, interested in the status of theories and laws and their relation to reality, and a sociological one, dealing mainly with the framework of scientific activity in a given society or environment.

These perspectives, which could also be described as internal and external, have been found to be most fruitful in the well-known works of Popper and Kuhn, respectively. It is doubtful, however, whether they are sufficient today. We have to take into account the profound changes which have marked the transformations occurring in economic activities, i.e. the increase in intellectual investment compared to physical investment, the growing role of complexity in the systemic framework (which until recently was particularly dominated by materialism), the emergence of sharing as the dominant form of communicating and circulating knowledge. Today we thus must consider knowledge from three different aspects: (i) the production of theories; (ii) the development of languages, and, (iii) the creation of communities; in other words, we see knowledge as a cognitive, rhetorical and communal device.

Thus, we can no longer discard the presence of tacit knowledge in any modern classification. And it is suggested that "codified" knowledge has to be subdivided into two regimes: those of "specialized information" and of "disciplinary knowledge".

The tacit degree of man/world complex relationship corresponds to the regime of common knowledge, characterized by a diffusion mechanism of "exposure". The explicit degree of the relationship between man and his world corresponds to the specialized information regime, with "teaching" as the communicative device. Finally, the disciplinary degree corresponds to disciplinary knowledge, to which "research" is associated.

We can thus assert that the activity of research is also the identifiable characteristic of the disciplinary fields of knowledge which appear by means of simultaneous "explicitation" and/or juxtaposed processes (for example, the social sciences).

Naturally, the practice of research will vary according to the "island of the archipelago" in question, that is, with the specific cognitive, rhetorical and communal strategies. To the criteria of science, based on the amplitude of empirical proof, the practices, or the method generally known as experimentation, correspond. But philosophy uses the method of analysis; ethics relies on the accomplishments of revelation; and aesthetics is characterized by a set of systematic procedures of construction/deconstruction. As if sharing was being tentatively "appropriated" by each grand domain of knowledge.

In the metaphor for knowledge, the central island of the archipelago corresponds to tacit knowledge, encompassing technical, political, religious and artistic areas.

Through the process of explicitation the network progressively extends and becomes more complex. Other islands appear: those of technology, law, morals, and fine arts. And then further away, through a more intensive thematization process, corresponding to the emergence of high precision languages, new islands of disciplines are seen.

3. Knowledge, Ignorance and Pseudo-knowledge

We may define true knowledge as that which lies inside the "boundary" of the archipelago; and ignorance as the "sea at large" that surrounds it. This sea can be conquered by constructing new islands, or by launching bridges to newly built offshore platforms or to other islands.

The archipelago is nowadays the locus of intense circulation of knowledge, in all directions, which reveals a real network character. Of course, pseudo-knowledge creeps up at every turn of the landscape, every time we want to swim (individually), or navigate (institutionally), in uncharted waters.

Pseudo-knowledge can be thought of as a group of sharks, or pirate submarines, that hunt along the shores or inside the canals of the archipelago, feeding on the discomfort of human souls. They try to disrupt the existing connections in order that their assertions cannot be verified. And only by using proper communicative strategies can they be overcome.

The archipelago is thus a heuristic metaphor, adapted to map knowledge in a situation of extended global activities characterized by intensive communication and networking processes.

But no classification is ever final. Maybe this was what prompted Leibnitz to deftly assert[5] that "the whole body of the sciences may be considered as the ocean, which is entirely continuous and without interruption or separation, even if men like to conceive parts in it and give them names according to their own convenience."

Knowledge and learning are the central resources and mechanisms of the new institutions, communities and organisations. So, the implications of the intensified circulation of knowledge will have to be recognized and fostered: disciplinary knowledge can only evolve in the context of a strong communicative framework which enables the attitude of sharing of meanings and values to realise its full potential. This is our fate and also our brightest opportunity.

On the other hand, our contemporary world is made of the networks which create, diffuse, finance, manage and support innovation, based on a group of formidable social, organizational and technological changes which were brought by the new process of producing technology from a science base. But these changes are societal, they are responses to the transformations experienced, involving all aspects of today's reality, concerning all networks of intense and enlarged communication that support our activity. Sharing has become in the new paradigm, a fundamentally communicative-reticular process.

We must be aware, though, that the present view of the world based on "knowledge" does not coincide with the view of the world of modernity, which is based on science. The vision brought about by the new paradigm of knowledge and information also favors "governance" rather than "government"; it promotes "global" values over "universal" ones. Further, it propels the complexity of the "environment" to obscurity and veils the beauty of nature.

Science and universals correspond to the realm of nature. Nowadays, science is understood as a factor of economic growth and innovation: science has been transfigured into "techno-science".

So we must not be surprised by the resurgence of ethics, now transformed into a theory of responsibility. Our moral world, made cohesive in medieval times by religion and, throughout modernity, by the idea of progress, now faces the tremendous challenge of reinventing a new cohesive "glue". Otherwise, it risks dissolving into blocks, a sort of "moral apartheid".

4. The Way We Experience the World

We live by interacting with what is external to our bodies, in a way that allows our survival. We can interpret, or represent "reality" through these interactive experiences and are also able to register them. As a result, the interpretations of past interactions can be stored in internal repositories, more or less organized according to the complexity of each individual. The "maps" of relations in which one has been involved along with their existence, as actual registers of past activity, operate as a guide to future interactions, or for the behavior to be exhibited in the course of activities we are engaged in the present.

Interactions with reality are a signal of our activity. This can basically take two forms. Physical alteration of the environment is a measure of the "action" of an individual (i.e.

the material, tangible activity). On the other hand, the alteration of the representation (or map) of reality is a measure of the "communication" (i.e. the intangible activity) engaged by the individual. So, any activity is in general a combination of tangible and intangible constituents. It is important to distinguish between them because there are cases where we deal with almost pure tangible activities like removing an obstacle, and others where almost pure intangible ones are involved like evaluating an alternative.

"We now know that observing or measuring is interacting, that a new theory needs to be developed to study and understand life."

Physical action and communication are thus the two fundamental components of every activity. The consideration of both is essential to the understanding of nature, of the universe and of the life it supports. Every living creature or system is perceived through its interactions in terms of action and communication or, more commonly, by a combination of both. Action corresponds to emission of energy. Communication corresponds to emission of information. We can thus say that a system is characterized by the emission of energy and information.

This simultaneous simplification and complication emerged after the grand unification (the equivalence between mass and energy) revealed by special relativity. Energy is a conservative physical quantity and has therefore the property of being conserved in any closed system. Information, understood as physical order, or arrangement, or more generally as "form", is not conservative. Furthermore, information is not totally captured by an observer, who only grasps what is relevant from it and discards the rest. This aspect—relevance to the subject—is associated with the notion of "meaning". The repository of meanings is what is usually described as "knowledge". By being non-conservative, meaning is at the origin of the difficulty experienced so far in inventing a physical theory of knowledge.

5. Information and Meaning

Each interaction with reality results in a meaning. These meanings constitute a representation of reality, a context in which new meanings are derived and made coherent. Highly social beings aggregate themselves in communities which evolve according to the composite influence of external factors (physical space and its climate) and internal factors (capacity of survival in their surroundings and cohesion of the group). These communities can be envisaged as open systems, exchanging continuously energy and information with the environment, their possibility for survival arising precisely from the capacity to sustain those exchanges. They exhibit the properties of self-organized systems. They behave as dissipative structures.

Therefore their cohesion and cognitive content are finite. They tend to align and organize their representations of reality in order to enhance their overall action and communication, with the aim of securing and eventually increasing the level of their collective cognitive potential. The effort to survive led to the emergence of "worldviews", i.e. sets of explanations and precepts to guide the daily activities of the communities and their relations with the neighboring ones.[6]

A worldview is an essential ingredient of cohesion in a group evolving in time. Like the fitness of its members and the way they organize themselves. Clearly, we devise more easily indicators of physical action than assess and measure the value of communication.

"Everything is connected today. And this is precisely what complexity is about: the impossibility of separating the system from the context, the living being from the environment, the object from the measuring instrument, ontology from epistemology."

This is due to the success with which for almost two centuries scientists experimented and theorized about the inner workings of nature. It required strenuous observations, designing new instruments, repeating and creating new experiments, invent and define new concepts, establish new relations.[7] Finally, it was possible to differentiate and emancipate the concept of energy from the notions of force, of heat, of temperature and be able to measure the capacity to produce work in a rigorous manner.

But in the end it was chiefly the current acquaintance with machines using energy exchanges (such as engines) that led to the pervasiveness of the concept of energy in daily life. Similarly, today most common machines incorporate programs and pre-defined instructions to obtain definite effects and modes of operation. Computers and electronic networks are found everywhere and information processing, big data, mobile access and financial transactions are overwhelming. "One is now, perhaps for the first time, ready for a real theory of meaning (…) adapted to handle the most significant but difficult aspects of meaning, namely the influence of context."[8]

Why was it not conceivable before? It is easy to trace where the trouble originated. The nineteenth century's fundamental premises about knowledge were composed of determinism, reductionism and dualism. Dualism consists in the belief of observer independence, reductionism in the use of mathematical language and determinism in the conservation of information. These assumptions represented the triumph of science as the engine of modernity. It was the time when it seemed that the edifice of classical physics was only perturbed by two little clouds.

However, these clouds evolved into the major physical theories of the following century, which were the basis of contemporary technologies and critical infrastructures of the economy. We now know that observing or measuring is interacting, that a new theory needs to be developed to study and understand life, and that information and meaning are non-conservative. The problem is that deeply entrenched beliefs take time to leave the stage.

6. Coda: The Techno-scientific Transformation

We live in a world of uncertainty. But this is the way we have always lived! We had to invent mechanisms to reduce uncertainty by proposing order and classifying reality. But finally, everything that exists either adapts or disappears. But the crises we are enmeshed with in our times bring not only more uncertainty but they are also complex by nature. Everything

is connected today. And this is precisely what complexity is about: the impossibility of separating the system from the context, the living being from the environment, the object from the measuring instrument, ontology from epistemology.

The promise inscribed in the charts of all the Academies of Science since the 17th century, of "making society progress through the applications of science" was finally fulfilled by the mid-twentieth century. Science progressed immensely, propelled by the world wars' efforts. The first science-based technologies saw the daylight during the 1940s to never leave our world.

Their transformative power was such that neither the military, nor subsequently the operation of the markets, allowed science to return intact to its curiosity-driven nest. Techno-science was born. Being progressively pulled away from curiosity-driven science, techno-science was able to grow enormously, erecting a formidable structure of networks of institutions that impacted the economy decisively.[9]

The "oil crises" of the 1970s set the stage to the deployment of the first socially selected products of techno-science: the information and communication technologies. A new period of techno-economic structural development was initiated, a period in which we are still living in, approaching the maturity of the solutions that those science-based technologies have provided for the time-span of two generations. New solutions will no doubt follow.

These solutions are naturally associated with a whole array of new issues. Information and communication at big distances seem to have exploded—a transformation that has profoundly changed our perception of life and how we live on our planet. Physical space has "shrunk" and information circulates the world at the speed of light. Further, images can now be digitalized for the first time in history, which constitutes a formidable revolution. Digitalization of images will impact society in a comparable manner to the invention of writing.

So, time is ripe to elaborate a new theory of information, capable of dealing with meaning and assessing the influence of context. The successes (and limitations) of Quantum Mechanics and the study of life rocked the foundations of classical physics. A new concept must be proposed for the dimensions of information, as universal as that of energy for the physical world of action. Maybe we will need to differentiate and emancipate the notion of meaning from the realm of natural language, information from uncertainty and probability, and to quantify relevance for the observer in a standard context.

Two decades ago, we tried to use entropic measures of information to describe the loss of cohesion of economic structures which corresponded to decisions to innovate.[10] We took the data on world primary energy sources, means of transportation and the diffusion of hybrid corn in several states of the US, provided by Cesare Marchetti in an illuminating paper.[11] We observed that once the determinant factor in each case approached a definite fraction (1/e) of the total of possible deployments, a new structure emerged.

It was a promising beginning, but one which only scratched the surface of the problem. We searched for more data but also undertook a more formal path,[12] inviting a group of scholars in philosophy, arts and humanities, social sciences and natural sciences, to discuss the contours and content of the concept of "form" (the label for a possible conservative entity

in the field of information and communication). We were certainly approaching a fraction of 1/e (36%) of what we could possibly do when the cohesion of our group collapsed.

But we firmly believe in this endeavor, as Shannon and Weaver signaled earlier on. We must go back to the basics.

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Notes

1. J. Caraça, *Science et communication (Paris: Presses Universitaires de France, 1999).*
2. M. Carrilho, *Rhétoriques de la modernité* (Paris: Presses Universitaires de France, 1992).
3. P. Burke, "*Encyclopaedias and the Fragmentation of Knowledge, 1450-1750", communication to the Colloquium "The idea of an Encyclopaedia: technologies of classification and the ordering of knowledge", Cambridge: (July 2001).*
4. J. Caraça and M. Carrilho, "A new paradigm in the organization of knowledge", *Futures 26, (1994): 781-786 and "The role of sharing in the circulation of knowledge", Futures 28 (1996): 771-779.*
5. G. W. Leibnitz, *Opuscules et Fragments inédits (Hildesheim: Georg Olens V., 1966).*
6. J. Caraça, *Science et communication*
7. A. Gouvêa Portela and J. Sousa Ramos, *Grupo Forma Bulletin*, mimeo. June 1994.
8. C. E. Shannon and W. Weaver, *The Mathematical Theory of Communication (Urbana: Illini Books, 1964).*
9. J. Caraça, "Globalization Trapped", *Cadmus 3 ,no. 2 (May 2017): 1-9.*
10. F. C. Rodrigues and J. Caraça, "Uma medida entrópica para as mudanças económicas", *Mem. Acad. Ciênc. Lisboa XXXI, (1990/ 1991): 67-72.*
11. C. Marchetti, "Society as a learning system: Discovery, Invention and Innovation cycles revisited", *Technol. Forecasting and Social Change, 18, pp. (1980): 267-282*
12. A. Gouvêa Portela and J. Sousa Ramos.