A Great Revenge? Social Sciences' Rising Pertinence in Scientific Research and Technological Innovations

Kléber Ghimire[1]

Received: 14 September 2017 / Accepted: 27 November 2017 /
Published online: 15 December 2017

Abstract The relationships between social and natural sciences are made of hierarchies and prejudices. But with the result of moving to applied goals and outputs, science is required more and more to integrate diverse observations coming from social sciences. The corroboration from the social sciences perspective has become necessary not only for comprehending the emerging societal viewpoints, but also gaining the very validity of the substance of knowledge on many of the embryonic fields of scientific research and technological innovations that science seeks to successfully observe and experiment. Overall, in matters of knowledge creation, social sciences have tended to show a considerable latitude in addressing different facets of emergent trends, causalities and manifold consequences, thereby giving rise to the balance of power largely shift in their favor.

Keywords social sciences rising pertinence・emerging frontiers of technological innovations ・linkages between natural and social sciences・natural sciences and predictive knowledge・ethics as scientific knowledge

Introduction

While natural and social sciences are both engaged in a common pursuit of generating new knowledge, their contributions are, as it is widely known, not weighed equally. Social sciences are typically described as "soft sciences", inferring that they lack rigor and objectivity. On the

✉ Kléber Ghimire
ghimirek@yokohama-cu.ac.jp

[1] Professor, Yokohama City University, Yokohama, Japan

other hand, natural sciences are frequently the object of high regard for their well-defined methods and the value of their discoveries to society. But to what extent is this reputation or achievement necessarily automatic or linear? We raise this question keeping in mind the recent context of evolutions in a number of new frontiers of technological innovations, which show a great deal of discontinuities, fragility in prognosis and uncertain applications, in addition to the persistent deficiency in social and moral penetrations within natural sciences. Social sciences too have their lot of weaknesses: danger of subjectivity, lack of autonomy from decision makers and funding bodies, inconsistency in interpretations[1], etc. Notwithstanding these problems, we believe the reflections from social sciences show certain assiduities and significance, and this to the extent that natural sciences may be advised to join social sciences in looking for their essential dynamism in the future.

Many existing perceptions of social sciences are well-known and some of them are likely to persist. One such perception is to purely dismiss this branch of knowledge, stating that it is value laden or contentious. Furthermore, its investigative approach is thought as being excessively broad and imprecise, thus unable to produce any meaningful empirical evidence. In view of this, its scientific level is perceived to be "extremely conjectural", basically comparable to that of "the literary critic" (Marshall, 1962, p. 22). In this regard, it may be reminded, for example, that, in the 1950s in the U.S., the center of the world academic excellence, when the National Science Foundation was created, deeming them completely unscientific, social sciences were excluded from its organizational structure and funding mechanisms for the promotion of scientific research and granting of scholarships and fellowships, due apparently to an active lobbying from many prominent natural scientists (Tanner, 1969, pp. 18-20). In around the same period, in Great Britain, on the other hand, even though social sciences were generally valued for their potential contribution to government policies and social improvements, the public funding to social sciences remained "modest in scope" (King, 1998, p. 417). Without a doubt, one would expect a similar trend in public funding to social sciences in many other European countries, given a largely comparable evolution in their industrial and trading activities and the prominent importance that they commonly accorded to natural sciences and technological innovations.

But luckily, there exists the second and less severe judgement on social sciences. This judgement recognizes that social sciences can be an important source of knowledge production. As such, a certain value of increased interactions between natural and social sciences should be recognized. For instance, since scientific investigations must occur in a particular social context, a greater grasping of basic tenets and explanations originating from such disciplines as history, anthropology, politics, economics, psychology and philosophy are regarded as worthwhile. This very last discipline, in particular, with valuable reflections from scholars like Popper and Kuhn in the past decades, provided important contributions to the critical study of science, showing many innate limitations in scientific methods, objects and explanations (Popper, 1972; Kuhn, 2012). These reflections took science itself as object, questioning its real ability to be "ideal in theory as well as in practice" (Andler et al., 2002, p.14). Indeed, philosophy has sought to deliver a robust analysis of science lacking not only the basic moral content (as will be discussed further below), but also provoking many extreme undesirable consequences such

[1] Obviously, the lack of autonomy from decision makers and funding bodies and the inconsistency in interpretations are equally valid to natural sciences as well.

as bio-medical engineering and ecological damage while attending to the narrow military-industrial interests, often with the "violent" consequence of "seeking to eliminate ways of life and ways of being" (Visvanathan, 2017, p. 47).

Nevertheless, natural sciences, master in their field, have felt always happy to tell social sciences 'follow my way'. It is all but enigmatic though why the writings from philosophy on science were tolerated, despite the fact they commonly employ methods of analysis that combine many intuitive and moral reflections. But as far as the core social sciences disciplines are concerned, replicating of natural sciences methods has been the way forward in acquiring partial acquiesce and repute. In some cases, this was self-imposed too. Here sociology and economics are two best examples. The former sought to utilize biological laws, physical and mathematical models in its early days of conception[2], while the latter has attempted to apply sophisticated mathematical models and tools in econometric analyses and game theories. Likewise, political studies have vainly looked for giving a more scientific stature by calling themselves "political science" by virtue of occasionally employing surveys, case studies and statistical analysis methods in line with the basic norms established by natural sciences.

Of course, there is a positive side of this as well: today there is rarely any field of social sciences learning that rejects empiricism, scientific rationalization and critical interpretation. Even history and archeology must use dating and other scientific methods of data gathering and verification using techniques and knowledge coming from disciplines as far as geology, botany, paleontology and astronomy. Social sciences doctoral thesis are probably the best indicators in showing how theorizing, hypothesis development and empirical rigor have commonly been integrated across social sciences. In actual fact, some observers believe that research in social sciences is more difficult to operationalize and "intellectually more challenging" than natural sciences like chemistry and mathematics because social sciences typically need to handle "so many uncontrolled variables" (Diamond, 1987, pp. 38-39).

Again, coming back to the specific issue of cooperation between natural and social sciences, there is also the reason often mentioned in the literature dealing with the history of study of knowledge that contributions from social sciences are important in areas where science is not particularly strong, namely in the area of social action. According to Habermas, even though natural sciences "produce technologically exploitative knowledge", "they are incapable of orienting action" (Habermas, 1988, pp. 18-20). It is not difficult to understand the underpinning of this reasoning: science generates knowledge and technological outputs intended for the betterment of society, yet their actual applications and any ultimate success depends on a vast array of issues such as the role of institutions, economic and political actors, prevailing social structures and popular mindsets. Furthermore, scientific and technological results are presented often in an oversimplified manner, frequently purporting their universal application. As a result, they are not always valid to divergent social or local contexts. In view of this, Habermas argues that "Social action is in the first place a cooperative activity mediated by tradition and taking place within ordinary-language communication that seeks answers to practical questions" (*ibid*,

---

[2] For example, in the first-half of the 19th century, Auguste Comte, considered as one of the founding fathers of Western sociology forcefully argued that knowledge must be based on established facts and laws away from personal intuitions or metaphysical speculations (Comte, Auguste, *Cours de philosophie positive*, http://classiques.uqac.ca/classiques/Comte_auguste/cours_philo_positive/cours_philo_pos_1_2.pdf, seen on 07/12/2017).

p. 20). Therefore, for seeking vital information and insights on institutional, social and cultural aspects, science must ultimately join social sciences in exploring and understanding these aspects. This too needs to be comprehended from global to local circumstances. After all, science is a product of society, for the reason that its own success in formulating new knowledge, whether theoretical or applied, invariably relies upon public investments in education and the core meanings and significances that society attaches to knowledge creation, learning and development of practical know-how.

Calling for a greater degree of communication or input from social sciences is however quite an easy task, especially when this is limited chiefly to the level of pure principle or general wish that does not oblige anyone to implement anything very concrete. This type of cooperation has regularly been stated. Yet, by and large, science in the past has been able to pursue much of its activities without having to cross paths with social sciences. But this may be changing.

An evolving context of rapprochement?

We would like to argue here that science today needs social sciences in order for it to advance. This is primarily because, with the result of moving to practical intents, science finds itself being increasingly confronted with the onus of having to go towards integrating observations deriving from social sciences. The corroboration from social sciences is vital not only for comprehending the emerging societal perspectives, but also gaining the very validity of the content and matter of scientific knowledge on many of the topics that science seeks to successfully observe and experiment. We believe this aspect has become especially conspicuous with regard to the recent scientific advances in areas such as artificial intelligence and other emerging technological frontiers. Some specialists perceive in this specific new evolution a beginning of the Fourth Industrial Revolution[3], thereby opening new prospects for expansion in business and industries, employment creation and improvements in living conditions for the poor as well as the creation of wealth for the rich (Schwab, 2017, pp. 29-96).

This sanguinity apart, in more recent years, numerous fields of technological innovations capable of bringing about unique positive changes in human societies are commonly stated. Some of these fields of technological innovations include: artificial intelligence, new generations of computers, robots, drones, space exploration, nanotechnology, 3D printing, bio-medical innovations, new energy concepts, and so forth. A number of these innovations have been known for some time already, but are thought to develop further both in their capacity and function such as computers or robots. At the same time, several markedly new innovations have begun to surface, attracting interest from the scholarly circles, specialized media and business sector; two notable examples are bio-medical innovations and artificial intelligence. The leading feature of these latest technological innovations is that they are anything but

---

[3] The first and second industrial revolutions are defined as the technological progress linked to the development of coal/steam based manufacturing and electricity/petro-chemical industrial activities in the 18^{th} and 19 centuries, respectively, while the third industrial revolution is assigned to the recent changes brought by the advancement in information and communication technology.

accomplished. Even when they are based on certain known facts or in the process of being established, there remains still the fundamental issue of how to renew intellectual curiosity in order to create additional knowledge. Besides, putting them into distinct applications is not always straightforward, especially when the initial phase of rationalization and hypothesis framing is based on narrow theoretical or laboratory-based observations. The essence of the present line of reasoning is that it is the social sciences that have now the potential of "liberating" science (or rather techno-science) in dealing with some of these complexities and impasses.

Pursuit of knowledge creation and its application

The recent technological expectancy surrounding artificial intelligence is a leading example facing many these problematical areas. The principal trait of this initiative is to seek to create machines that are greatly intelligent, primarily by copying human brainpower or even surpassing it. This artificial knowledge is expected to be beneficial for a variety of sectors such as medicine, robotics, military, informatics, education, finance and banking. Ironically, it should, among others, assist individuals in boosting their brains (especially when confronted with certain cerebral limits or designed to increase their capacity) thanks to the development of new intelligent software. In addition to this, this technology is expected to be useful for human "selective breeding": for example, by helping to enhance educational levels, nutrition, sleeping and exercise habits and by eradicating parasites and illness, including those affecting the brain (Bostrom, 2016, pp. 43-44).

Accordingly, apart from the question of whether different societies would want to choose such a path of "human augmentation", there are many fundamental and complex scientific questions that need to be dealt with in attempting to realize this innovation. In this regard, the major challenge is how to understand and replicate the human brain. This stems from the fact that the human brain possesses infinite capacities of plasticity in thinking, expressing emotions and displaying irrational behaviors (Cyrulnik *et al*. 2012, pp. 13-26). As such, it is difficult to reduce these various brain capacities to a limited number of predetermined structures or functioning. To date, much of the research undertaken in this area is derived from neurobiology and cognitive psychology based on certain observation samples or computer modelling of individual behaviour. This information thus tends to be highly partial. Consequently, how sensible is it to apply this fragmentary or even flawed knowledge to whole of a wider society? Most significantly, how should one comprehend the sum of cognitive differences or varying appreciations between individuals, cultures and geographies? In the end, whose brain should it be selected as a model in creating an intelligent machine software? Similarly, for rearing or reproducing of an augmented intelligent human species, in addition to the bio-medical aspects, there are multiple social and institutional facets that need to be understood in the ongoing research process. In particular, the challenge remains: how to map out the collective attitudes, reactions and opinions? At the same time, it is this collective posture that actually allowed the human species to be uniquely distinguished from other animals in the past, with much of this resulting in its capacity to dominate other animals and the existing ecosystem. Some historians concur that, based on this very capacity, humans are likely to remodel the future too, primarily for their own benefit (Hariri, 2017, pp. 132-133).

Space research is another area where the significance of this collective dimension is yet to be comprehended. Let it be granted that by virtue of enhanced scientific research and experimentations, the basic knowledge would eventually be created in dealing with fundamental problems like the availability of reliable and affordable travel technology and the lack of gravity, air, water and soil to grow food. But even so, the costs for space explorations are astronomical, supported so far through public finances, although certain authors have spoken of a growing prospect for public-private collaboration in the future (Harris, 2009; Bignami and Sommariva, 2016). More specifically, can a new and functional human society be constructed out of no resources, and this without the possibility of exploiting fellow animal species and earth's natural reserves like in the past or the contemporary periods? Much of the past and ongoing scientific experimentations have focused on individual ability to cope with travel stress and physical difficulties in staying in the space for an extended period of time. However, if the space settlement project is to be serious, many questions relating to the collective living and management of society will ultimately have to be dealt with.

For instance, in the economic sphere alone, a whole series of issues associated with production, consumption and redistribution will come to fore. This is especially so as productive resources are nonexistent in the space, even though venture capitalists and entrepreneurs have tended to suggest the existence of a great deal of economic prospects through mining on the Moon and Mars, the development of new generations of space technologies and the expansion of markets due to increased commercial activities linking multiple planets (for further details on these arguments see Valentine, 2012, pp. 1045-1067). Also, new systems of public administration, political representation and legal systems will have to be developed. Meanwhile, in the more sociological field, dealing above all with such issues as collective mobilization, power relations and equity will be far from easy. In particular, all this will make little sense if family institutions, reproductive and demographic conditions are not sufficiently grasped. After all, how desirable is the whole space project? Is there really any specific pressing need towards developing space settlements while the earth still possesses many uninhabited regions (vast deserts, north and south poles and oceanic zones[4])? All the same, social sciences have potentially the ability to provide greater discernment and elucidation on various these crucial aspects. It is possible that this prospective knowledge may even prove a new source of reflection within natural sciences in assessing its prevailing methods of theorizing and attempting to produce knowledge with multiple constituents in scientific investigations in general and in the area of space exploration in particular.

On other technological fronts, evolving at different speed and generating varying outcomes, it is not easy to pinpoint how and the extent to which interactions between natural and social sciences may take place in creating vital knowledge from the outset. Robotics does seem to be one such field. New generations of robots are expected to emerge with added intelligence, human appearance and diligence. They are thus predicted to be handy as educational and judicious mechanical tools. They are also expected to gradually cohabite with humans sharing their habitation, intimacy, even sexuality (Alexandre and Besnier, 2016, pp. 55-60). Besides the

[4] It may be noted that these various geographical areas, albeit their general inhospitable character, are nevertheless certainly more suited for future human settlements than the planets that have been discovered so far.

increased physical presence, these new generations of robots are expected to acquire knowledge in an autonomous fashion, possibly imposing their intellectual power on human beings. As such, some authors believe, apart from these challenges, there is the question of how to incorporate new mechanisms that guarantee the cognitive abilities of robots going as far as possessing an appropriate "social and emotional behavior, moral judgment, intentionality, so that machines can adapt socially" (Devillers, 2017, p.199). Many these issues call for sociological and philosophical verifications and discussions to which scientific disciplines have admittedly little new expertise to offer. Nevertheless, the real progress in this direction (i.e., robots interfering in our lives seizing our physical spaces and mental competences) is rather slow, if one ignores the popular journalistic writings, media coverage and promotional literature prepared by robotic technicians or their business enterprises. What explains then this languor? Is this merely due to the lack of research funds and prospective consumers or the scary image of or aversion to humanoid robots (because of their close resemblance to human beings) that seems to prevail in certain cultural contexts (e.g., in Europe and North America)? How solid is the scientific basis of these new generations of robots? These questions are especially valid, given the fact that, while much of the future robotic revolution is to come with the advancement in artificial intelligence technology, this latter technology is in itself still largely in a putative or uncertain state.

In the same way, with reference to nanotechnology and 3D printing, it has consisted of reasoning, based on the growing scientific and media interest that these technologies were becoming readily mature, producing intended results in knowledge generation and applied products. This is to the extent that the present forms of production and distribution of manufactured goods were to be supplemented, with the dawn of a new industrial revolution. On nanotechnology, it is suggested that, "the ultimate realization of molecular assembly would mean the end of the manufacturing industry", with a likely effect of bringing about "the demise of entire sectors of the economy focused on areas like retail, distribution and waste management" (Ford, 2015, p. 246). Similar prognostics have not lacked with regard to the 3D printing as well, with certain authors like Gershenfeld conjuring that a "Widespread access to these technologies will challenge traditional models of business, aid, and education" (Gershenfeld, 2012, p. 43). Evidently, no such fruition has taken place. On the contrary, both technologies have largely decelerated.

It is easy to see that nanotechnology has lost the momentum. Let us note that nanometer denotes one billionth of a meter, but there has been no scientific breakthrough in dealing with atomic and molecular matter on nanometer scale. Currently, nanotechnology can control matter and produce certain number of consumer and industrial products at the level of 100 nm or more, using basically the conventional knowledge and techniques accumulated in chemistry and materials sciences. This involves more of a miniaturization of products rather than applying of nanotechnology in a true sense. On the other hand, as nanotechnology has failed to produce anticipated results, government and corporate funds have dried up (Berube, 2006, p. 31) and the university faculties previously engaged in this specialty of work have now switched to other areas of research, namely artificial intelligence and robotics.

The 3D printing technology too, despite claims for major potential breakthroughs in providing individuals and collectivities with a range of affordable and personalized products, the actual outcome is quite scanty, constrained by the size factor (large products are difficult to produce by this technology), the availability of only a few types of raw materials (so far mainly plastic) that can be used to produce goods and the abundant and effortless accessibility of mass consumer products in the market. Furthermore, 3D printing has faced the major problems of standardization, maintenance and consistency. On the whole, it has not progressed much beyond the phase of prototyping (Urry, 2016, p.121). The recent trends suggest an actual decrease in the sale of 3D printers (Dilawar, 2016), hence the decline of the technology without never being entirely developed.

Currently, there is much discussion on the optimistic prospects of artificial intelligence technology broadening varieties of pioneering functions. And this discussion is occurring without any certitude that new artificial knowledge will be created corresponding or exceeding the human intelligence. It would not be extraordinary, if truth be told, that in the years to come each and every technology would be tagged as "artificial intelligence" even if this basically involves the common deployment of machines and computers to regroup, store and process information in a fast and organized manner. Does not this tell us a similar story of the nanotechnology in the recent past, when this technology was proclaimed to have made so many new innovations and appliances despite essentially producing diminutive objects and without reaching anything near to the nano-scale mark initially proposed?

On this list, let us add the energy issue. This is an area where significant knowledge exists in terms of vital concepts and findings. However, the main challenge appears to be the mobilization of economic and political actors, institutions and the wider public opinion. For instance, there has been no lack of scientific knowledge on the principal sources of renewable energy and methods of improving energy efficiencies. But putting this knowledge into practice has proven quite difficult. A full understanding of why this is so can only emerge from social sciences. Likewise, there is in recent years much discussion on the production of energy through nuclear fusion and uncharacteristic concepts like antimatter energy (using of matter with opposite electronic charges for producing energy) (Close, 2009) or zero-point energy (energy produced in a substance at the temperature of absolute zero) (King, 2001) have also been evoked. While some of these notions are at the early stage of scientific explorations and verifications, any major positive outcome in these areas and especially attempts to put them into eventual practice would mean having to deal with a similar range of complicated questions going beyond the scope of the work usually undertaken within natural sciences disciplines, such as physics or chemistry.

In sum, many of these aspects showing the apparent weakness in producing anticipated scientific results in various technological areas can form an important topic of research and analyses within social sciences. More crucially, these are some of the notable areas where natural sciences, especially the branches directly implicated, have basically failed to live up to expectations. So the fundamental question is: why does this happen? What makes natural science to constantly display exaggerated optimism despite an apparent failure in yielding expected outcomes?

Scientific studies on wider consequences

Scientists and engineers by their very nature limit their work to testing a fixed theory or creating a specific device. The main intent of this is to produce a well-defined and tangible result, with the aim of satisfying customer or societal needs. This method, although respectable on its own merit in many respects, nevertheless poses a problem for attempts to explain the phenomenon in its entirety. In particular, it tends to leave out many essential elements that make the complete chain of the subject matter under consideration, including its overall configuration or evolution. This is not about lacking of a sample size or hypothetical objectivity. Rather, this is about the fundamental problem of a restricted vision in its overall scope or analysis. This is also about bias, as there is usually a tendency within various branches of natural sciences to put a singular emphasis on the initial part of the "chain", leaving out its remaining parts, especially the final segment. It is in this sense, precisely, that the authors like Hans Jonas remind us of how this state of affairs has made the "predictive knowledge" base to be notably circumscribed within pure sciences, arguing further that "the truth about predictable future conditions of mankind and the earth" is "a matter of scientific (not philosophic) knowledge". He also believes a simple theoretical benchmark of "certain", "probable" or "possible" scenarios on the consequences of a given technological innovation might be adopted in seeking to produce predictive knowledge (Jonas, 1985, p. 26). Thus the question arises: are there any prospects for the prevailing mindset or situation being changed? What does the present context of scientific inquiries or technological innovations tell us?

Naturally, there are great difficulties in seeking to alter the status quo. Basically, there has to be consistencies in methods of investigation and the analysis of results. This implies, to begin with, a different form of hypothesizing, capable of accommodating a sequence of scenarios. This also implies the creation of a step-by-step and broader experimental data base, with the critical need for categorization in which key information and ensuing ideas are distinguished and grasped. Most of all, the whole process must remain open to diverse interpretations. Given this, both positive and negative dimensions need to be taken into account in their totality. But for historical reasons (i.e., the attachment to the ideals of scientific progress and propitious changes in human security and comfort), as well as being beholden to financial and institutional sponsors, science has the propensity of over emphasizing optimism. In matters of creating true knowledge, we believe there are no obligations to showing the positive side in an exclusive manner. After all, the positive and negative aspects together can only make the sum-total of any credible knowledge.

In spite of this, as for the recent scientific experimentations and novelties, only the positive traits are put on full display. Whether it is the field of artificial intelligence, new computers, robots, space exploration, nanotechnology, 3D printing or bio-medical innovations, their pure beneficial outcomes are underscored. Their possible negative consequences, on the other hand, are often ignored or treated merely in a trivial way. In any event, attempts to integrate potential positive and negative aspects of scientific investigations and technology development in research design and experimentation processes are rarely there. This makes it particularly arduous to achieve a realistic balance sheet; and subsequently, even the potentially advantageous outcomes may appear suspicious in the public eye.

Indeed, how can one be sure about any positive effects of scientific experimentations and technological development when these activities are taken in isolation from wider societal effects, especially when one reads that even a benign product like aspirin may cause a whole list of serious consequences when taken on a regular basis: loss of appetite, depression, vomiting, macular degeneration, stomach bleeding, liver and kidney damage, and even death?

Equally true is that we still do not know why aspirin is effective when that is the case. In any event, it appears that the debate concerning the negative side effects of aspirin had begun already at the beginning of the 20th century, only after a few years of its manufacturing and marketing that began in 1899 (Dockray, 1905, pp. 1692-1693). In the same way, we use today so many products made from petro-chemical substances detrimental to human health that, it is only the question of time when their negative effects will become too obvious. The point here is that, since even those technologies and products which are commonly used and are seen to be most expedient may ultimately transpire harmful, it is not difficult to imagine the long-term severe effects of many of the powerful evolving scientific inventions today. For example, it is quite evident that, in the event that they become fully developed and widely applied, nano-machines, equipped with artificial intelligence and operated through robots and drones, can cause great human tragedies, as well as enduring effects on animal species and the environment. But it is also likely that, after considerable financial and intellectual investments, these technologies are able to generate, in chorus, certain positive outcomes as well. Currently, certain products with nano-particles have been brought to the market like wearable objects, adaptive optics and industrial pipes which are seemingly lighter, more solid or practical. In brief, this calls for conceiving of an integrated and open-minded investigative methodology that will permit to distinguish potentially dangerous outcomes from that of beneficial ones, upon which public institutions and enterprises may act positively and that an informed public opinion could be formed.

Viewing ethics as part of a knowledge building exercise

Many of the dilemmas concerning the recent scientific explorations and technological progress mentioned above give rise to multiple ethical issues, to which science harbors an uneasy relationship. The foremost problem in this regard is that science does not see ethics as part of a knowledge building exercise. As a matter of fact, a widely held conception has been, as stated succinctly by Marie Curie (widely acclaimed for her pioneering work on radioactivity) that "science deals with things, not people" (cited in Holton, 1998, p. 248). According to this conception, since ethics are values seen to be mere judgements or idealism embraced by individuals or social groups with particular interest or cultural and geographical backgrounds, they cannot be the affaire of science, which is concerned primarily with demonstrable logic, facts and laws.

The history of intellectual interest on moral considerations is long and rich. From early civilizations onwards, influential religious thinkers and philosophers commonly evoke this fundamental dimension, often as a way to uncovering the truth and helping individuals and societies to lead a more just and gratifying existence. For Confucius, for example, "a gentleman who is widely versed in letters and at the same time knows how to submit his learning to the restraints of rituals" and "Goodness" "is not likely, I think, to go far wrong" in following the right way (*tao*) (Confucius, *The Analects*, 2000, pp. 24, 112-113). Kautilya, a well-known *Vedic* philosopher of 4th century B.C. India, writes that "Philosophy is the lamp that illuminates all sciences" (Kautilya, 1992, p. 84). He uses the expression "philosophy" in the sense of wisdom and the right way of living, while the term "sciences" is employed to denote as the essential sources of knowledge for sound discernment and advising in such spheres as politics, economy and justice (*ibid*, p. 20). But in this specific area of reflection, no philosopher is as explicit as Aristotle, a prominent inspirational figure in Western modern scientific thought. He identifies three sources of knowledge: theoretical knowledge (*episteme*), skill and craftsmanship (*techne*) and wisdom (*phonesis*). In particular, he states that "Wisdom will be the most complete forms of knowledge" (Aristotle, 2007, p. 310). But the Western scientific thought adopted only the first two types of knowledge, i.e., science and technology, but largely left out the dimension of "wisdom". We may ask why? Among various reasons, it is possible to indicate, first, that ethical issues are difficult to investigate through standard laboratory experimental test methods, especially when scientists and technicians tend to remain largely hermetic in their specialized domains. Second, an attempt to uncover ethical questions may even prove hazardous in some circumstances, given that this can show frequent inherent flaws in individual and teamwork endeavors of many scientists and technicians: in-built blind beliefs, self-interests, over-toning of success, etc. Third, and more crucially, any serious consideration of ethical aspects ultimately entails the necessity of having to deal with intricate broader questions of where the society is heading for. Who are the individuals or social groups that are most likely to gain and those who are likely to lose? Is a chosen path desirable, and under what circumstances? In particular, should scientific and technological undertakings occur in a self-governing, autonomous manner, or should they be guided by wider political and moral considerations as well? The complexity of these questions are such that, basically, the average scientists or technicians can have no competence to deal with them satisfactorily.

Seeking to separate "good" from "bad" is always an intricate task, and for that matter, it is not the exclusive affair for natural or social sciences. Nevertheless, natural sciences are known to be governed by a certain form of mind set, affirming that the only possible route to creating knowledge is to search for "measurable facts" fully detached from human or societal factors. The result is, as has already been pointed out, the building of knowledge essentially on laboratory confined approaches and methods. Still, even in a context as restricted as this, an ethically conscious effort can make certain differences.

Let us refer again to the emblematic examples of aspirin, petro-chemical products and nanotechnology research. One could allow that aspirin and petro-chemical goods, produced at a time when scientific optimism was at its height, a careful inventory of their potentially negative effects would not have been realistic the same way or as much as their positive effects. But today such an assessment is fairly conceivable. And, concerning the nanotechnology, as it constitutes a rather new and evolving area of scientific research, creating relevant knowledge differentiating and classifying the "positive" and "negative" outcomes are entirely feasible, and this largely within the existing scientific parameters.

Of course, an effort to create a deeper knowledge covering key innovations within various branches of learnings across-the-board would require a more systematic and comprehensive thinking and new methodological explorations, first, within natural sciences and then going towards social sciences for further enrichment and synergy. The issue here is not whether this effort leads to indicating mainly the positive effects or, on the opposite, the misgivings of scientific activities. Both kinds of effects can help, in the end, only to increase the greater reservoir of knowledge. This is precisely why it is so crucial that ethics is viewed as intrinsic to knowledge creation.

Conclusion

What useful conclusions can possibly be drawn from the foregoing discussion, noting that several of the elements evoked still require further work and clarifications? One, for sure, is that, increasingly, conventional experimental methods originating from natural sciences seem to show considerable strain in comprehending the broader factors and realities characterizing the myriad of evolving technological projects and scientific experimentations today, such as artificial intelligence, new generations of computers, nanotechnology, 3D printing, space and new energy concepts. Nor do these methods, limited in scope and time, allow us to fully examine their evolution and related consequences. Furthermore, many of the knowledge creation activities have tended to focus exclusively on their positive outcomes, thereby leaving the "knowledge bottle" half-empty. At a time when principal scientific theories and *doxa* are exhausted, including their recycling, these lacunae make the natural sciences' traditional role of game-maker in matters of knowledge creation especially precarious.

So the question is: Can science invent a modus operandi for self-reflection embracing a new and more open methodological approach? This would logically mean reassessing many of its pre-set formulas and ideas. In saying this, we are obviously not affirming that its usual exigencies to produce conceptual, objective and empirical knowledge are futile. Rather it is to suggest that this approach, combined with a more malleable logic and method in theorizing and experimenting, can facilitate the examination of fundamental problems or issues in their various facets and successions, and this from their very roots and in their full dimensions. Accordingly, this would imply that research designs and analyses are made amply adaptable. We believe this suppleness is the key to enabling science to doubt, temper down excessive positivism and admit errors more readily. This is the second set of reflections that we draw from the preceding sections.

Finally, the present inquiry tends to gravitate towards important implications for cooperation between natural and social sciences. The latter branch of knowledge, by its very nature and for the reasons already mentioned, espouses methods and objectives privileging reasoning, the formulation of a doable hypothesis with explanatory content and the analysis of results that can accommodate a larger number of variables. Moreover, social sciences perspectives can offer a more long-term historical narratives, thereby facilitating better understanding of the related evolution, outcomes, upshots and significations. In light of this, social sciences have considerable latitude for addressing the different facets of the emergent trends, causalities and manifold effects of the recent scientific observations and technological changes. When truly attached to spirit and principles, this ensuing knowledge has the significant potential for encouraging self-reflections, criticism and renewal of ideas. In other words, there is much to be gained by forging a clear bond or even a convergence between these two key sectors of knowledge. No doubt, "union" and "identity" are always complex issues. Nevertheless, in the past social sciences turned to natural sciences in looking for inspirational methods and stimuli. Will the natural sciences be able to do the same in the future, i.e., going towards social sciences?

References

Alexandre, L. and Besnier, J.-M. (2016). *Les robots font-ils l'amour ? Le transhumanisme en 12 questions.* Paris : Dunod.

Andler, D. Fagot-Largeault, A. and Saint-Simon, B. (2002). *Philosophie des sciences*, vol. I. Paris: Gallimard.

Aristotle. (2007). *Ethique à Nicomaque*. Paris : Librairie J. Vrin.

Berube, D. (2006). *Nano-hype*: *The Truth Behind the Nanotechnology Buzz*. New York: Prometheus Books.

Bignami, G. & Sommariva, A. (2016). *The Future of Human Exploration*. Basingstoke: Palgrave Macmillan.

Bostrom, N. (2016). *Superintelligence: Paths, Dangers and Strategies*. Oxford: Oxford University Press.

Close, F. (2009). *Antimatter*. Oxford: Oxford University Press.

Comte, A. *Cours de philosophie positive*, http://classiques.uqac.ca/classiques/Comte_auguste/cours_philo_positive/cours_philo_pos_1_2.pdf, seen on 07/12/2017.

Confucius. (2000). *The Analects*. New York: Everyman's Library.

Cyrulnik, B., Bustany P., Oughourlian, J.-M., André, C., Janssen, T., Van Eersel, P. (2012). *Votre cerveau n'a pas fini de vous étonner*. Paris: Albin Michel.

Devillers, L. (2017). *Des Robots et des Hommes: Mythes, fantasmes et réalité*. Paris : Plon.

Diamond, J. (August 1987). Soft sciences are often harder than hard sciences, *Discover*, pp. 34-39.

Dilawar, A. (13 June, 2016). The 3-D Printing Bubble may have Burst, *Newsweek*.

Dockray, J.S. (December 1905). Some Toxic Effects of Aspirin, *The British Medical Journal*, pp. 1692-1693.

Ford, M. (2015). *Rise of the Robots: Technology and the Threat of a Jobless Future*. New York: Basic Books.

Gershenfeld, N. (November/December 2012). How to Make Almost Anything: The Digital Fabrication Revolution, *Foreign Affairs*, Vol. 91, No. 6, p. 43.

Habermas, J. (1988). *On the Logic of the Social Sciences*. Cambridge, MA: The MIT Press.

Hariri, Y. N. (2017). *Homo Deus: A Brief History of Tomorrow*. New York: HarperCollins Publishers.

Harris, P. (2009). *Space Exploration: Living and working Offworld in the 21st Century*. New York: Springer Praxis Publishing.

Holton, G. (1998). *The Scientific Imagination: Case Studies*. Cambridge, MA: Harvard University Press.

Jonas, H. (1985). *The Imperative of Responsibility: In Search of Ethics for the Technological Age*. Chicago: University of Chicago Press.

Kautilya. (1992). *The Arthashastra*. Gurgaon (India): Penguin Books.

King, D. (July 1998). The Politics of Social Research: Institutionalizing Public Funding Regimes in the United States and Britain, *British Journal Political Science*, Vol. 28, No. 3, p. 417.

King, M. (2001). *Quest for Zero Point Energy: Engineering Principles for "Free Energy"*. Adventure Kempton, IL: Unlimited Press.

Kuhn, T. (2012). *The Structure of Scientific Revolutions*. Chicago: University of Chicago Press.

Marshall, T.W. (March 1962). The Natural and Social Sciences, *Caribbean Quarterly*, Vol. 8, No 1, pp. 13-24.

Popper, K. (1972). *Objective Knowledge: An Evolutionary Approach*. Oxford: Clarendon Press.

Schwab, K. (2017). *The Fourth Industrial Revolution*. New York: Crown Business/Penguin Rando House.

Tanner, L. (May 1969). Big Science and Little Science, *The School Review*, Vol. 77, No. 1, pp. 18-31.

Urry, J. (2016). *What is the Future?* Cambridge: Polity Press.

Valentine, D. (Fall 2012). Exit Strategy: Profit, Cosmology, and the Future of Humans in Space, *Anthropological Quarterly*, Vol. 85, No. 4, pp. 1045-1067.

Visvanathan, S. (2017). "An Invitation to a Thought Experiment: Quality, Diversity and the Epistemics of the University". In Kumar, R. C., *The Future of Indian Universities*. New Delhi: Oxford University Press.