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On the Role of Ethics in Shaping Technology Development

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Abstract

Important changes are taking place, currently, regarding the role of ethics in technology, particularly, in the context of the fourth industrial revolution. The adoption by the General Assembly of United Nations of the resolution A/RES/70/1 on September 27th, 2015, entitled "Transforming our world: the 2030 Agenda for Sustainable Development", better known as "sustainable development goals", is making that different international organisations and countries adopt it as the minimum reference ethical framework for assuring that this revolution in course supports and contributes to achieving these goals. To better understand these changes, it is important to make a historical reference to how technology and the role of ethics were understood during the past 50 years. In this paper, I take as reference the influencing book "*The Challenge Presented to Cultures by Science and Technology*" (1977) of the Genevan philosopher Jean Ladriére, some ethical proposals made during the '90s, to end with some recent European Union (2019) and World Economic Forum (2018) ethical proposals. I conclude that there are continuities and discontinuities, first in the conception of science and technology in Jean Ladriére and others, and how recent proposals are approaching the issue, second on the role of ethics in this fascinating and revolutionary process. However, we may envisage a radical transformation of the conception of technology in the context of the worldwide request of shaping the fourth industrial revolution.

Keywords: Ethics; Ethical Shaping of the Fourth Industrial Revolution; Technology Development; Human Sustainable Development; Sustainable Development Goals.

1. Introduction

Ethics is called to play an important role in this fourth industrial revolution. It has to shape, as called by the different platforms of the World Economic Forum, the future of this revolution in course, to guarantee that it contributes to enhancing human welfare and the protection of the environment. Humanity is doing important steps in this direction as we will see. One of the ways to better appreciate it is presenting some historical momenta on how technology and ethics have evolved. I am dealing with, in a sketchy way, some considerations on technology and ethics.

Our starting point is the publication of Ladriére´s book *The Challenge Presented to Cultures by Science and Technology* in 1977 [1]. It was the product of the colloquium on "Science, Ethics and Aesthetics" that took place in 1974 and was sponsored by UNESCO. The book originally titles *Les enjeux de la Rationalité* and was published also by UNESCO. It deals with the relationships between science, technology, and culture. This publication is important because it was one of the first books which discussed the impact of science and technology in ethics and culture. Four main mechanisms of impact were devised: a) extending the scope of ethics; b) creating new ethical problems, c) suggestion of new ethical values and d) new ways for determining norms [1]. But before discussing this approach and mechanisms, it is important to make some remarks on technology.

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2. Research Methodology

In this study ethics and technology are investigated. What is observed is that every time ethics is more relevant for shaping technology. Traditionally we find two groups conceptions of technology: the first one, emphasises technological products and how these impacts societies and the environment; the second one, emphasises the process of development of technology. What is observing now is that these two groups of approaches are relevant and should be taking into account to prevent intentional or unintentional harm, and to make the technology be at the service of improving and enhancing humans, and to reduce impacts on the environment. The three main moments I have followed, on the role of ethics in technology, can be charted in the following way:

Figure 1. Research methodology flowchart

3. Brief Historical Context

Technology can be approached from different perspectives, not necessarily inconsistent between them. One assesses how technology has penetrated and transformed cultures, societies, and the manner of living of humans or the progressive environmental negative impact due to the intensive use of technology in all the spheres of human activities; and the strategies for dealing with them. Closely related to it, other perspectives emphasize how the technological activity is socially organized, becoming like the enterprise of science, and the mechanisms that make that technology becomes tightly related to science, i.e., providing important and precise tools for advancing scientific knowledge, and at the same time, the use of scientific knowledge to develop new and more sophisticated technological products. From this perspective, it is fundamental to point out the connection of technology with the development of the industry. The technology was the key to three previous industrial revolutions, including this new revolution.

A third interesting approach was proposed by Papa Blanco (1979) [2]. This author organized technological products according to "the nature of what it produces". Three domains are relevant: matter, energy, and information. The action on matter produces physical arrangements, devices, and transformable materials, which further are transformed into equipment and other technological products. The action on energy yields energy usable in different forms: chemical, electrical, magnetic, and related technologies. Finally, the action on information yields information used in technology and for consumers. The technological process forms a cycle in which new equipment, for example, is used to improve the use of matter, to obtain new forms of energy or new ways to foster the use of information. At the same time, these cycles tight the relations between science and technology.

Drawing an analogy between internal and external historiography related to Programmes of Scientific Research [3] we may call the above approaches as "external perspectives", due to its centrality on how technology production organizes and impacts society, culture, and environment.

Another group of approaches to technology emphasizes the process based on the internal intentionally of technology. Some of the basic features of this intentionality can be summarized as follow:

i) Technology is a process that transforms an undesired situation (or reality if we prefer) into a desirable one. "Desirable" doesn´t indicate an ethical value, but the transformation if a situation according to a previous purpose. These undesired situations are the inputs and the starting point of the technological process. The intentionally of technology is the introduction of a "product" into reality, and in doing it reality is transformed. For example, the construction of the Pascaline calculator by Pascal responded to a specific intention: to reduce his father´s manual process of counting. In this sense, the problem is to make it easier and accurate the process of counting; the product or object is a mechanical device or machine.

ii) Technology is an intentionally driving process. The technological process is closed under the (undesirable) situation analysis. In formal terms, $T(P) = O$. It takes a problem; apply some transformation (T) to produce an object (O as the solution). Given that T is a complex process (with several stages) it is better expressed as $\overline{T}(P) = 0$, to indicate that it is a (partial) recursive process. The technological transformation process, then, transforms the problem into a design, the design into an implementation; this implementation needs to be tested, and the final result is the object produced or released. In one first account of what is considered a technological object, we may include: machines, devices, parts, tools, software, and biotechnological (genetic engineering) products.

Following Aguero and Sasgupta (1987) [4], we may schematize it in the following flow process. As observed, there are several feedbacks in this process that makes that the object produced could be transformed into a new problem; the implementation feeds the design, and tests feed implementation and design.

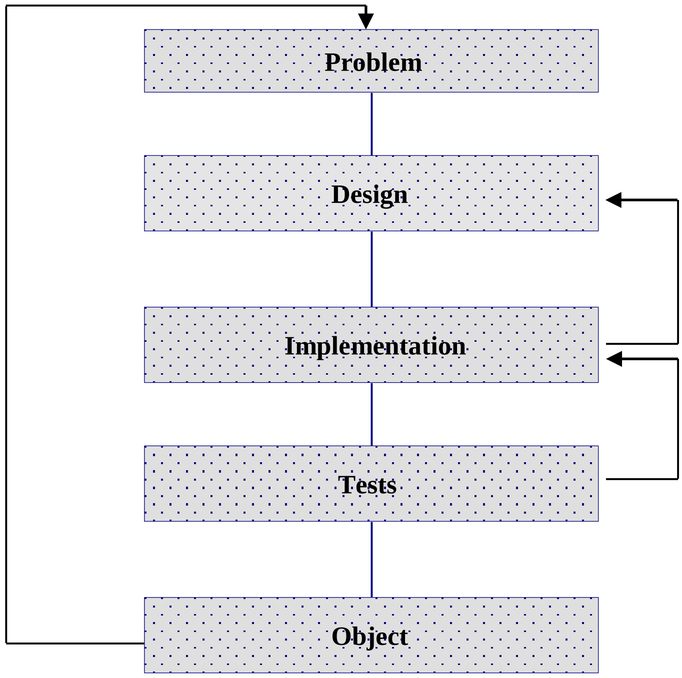

Figure 2. Technological process

As can be seen, there are different loops in the process to indicate the fact that these different components can modify decisions previously taken (to a determined limit). It is important to indicate the loop that goes from the Object to the Problem the originated the technological process to this remark this feature of technology that consists of continuously improving the quality of the technological products yielded in a determined moment. Several trends motivate this process of improving: advance in miniaturization, when corresponds, the incorporation of new functionalities, achieving new levels of integration to improve performance, and new materials, among others.

iii) Design accumulation. This feature indicates that the technological process conserves an important degree of accumulation in design. Those components that have proved to work very well from a structural and functional perspective of use, tend to be conserved in the new designs and production of new technological objects. But also, successful methodologies are integrated into the technological process. As pointed out by Edgerton (2006) [5] complete innovation is not the driven motif of the technology process, in many cases. Objects entirely new are very rare. But what is observed is a tendency to use old fashioned components in different ways or using different materials with new properties in which these parts or designs are used.

iv) Technology as a design-centered process. It has become more and more clear the role of design in the current technology process. Several reasons support it. First, technology tends to be a very highly standardized activity. The better way to meet these standards is by taking them into account from the beginning of the visualization of the object to be produced. Second, technology production is strongly influenced by the incorporation of scientific research results, mathematical developments, other technological achievements, and ethical issues too. The design is the best place to deal with them. Third, recently we have observed a strong tendency toward considering the technology process as part of a technological system, as I will emphasize later.

The design centrality of technology was first proposed by Skolimowski and Simon (1966) [6], however, few philosophers have discussed technology from this perspective. In Franssen, Maarten, Lokhorst, and van de Poel (2018) [7], it is found a brief account of authors and philosophical trends related to design-centered technological processes. The situation is different in science and engineering, and in engineering education [8], in which it is very common to refer to design as a key component of engineering and also scientific practice.

Given the importance of design, and following again to Aguero and Sasgupta (1987) [4], we may represent the design component in terms of four main sub-systems.

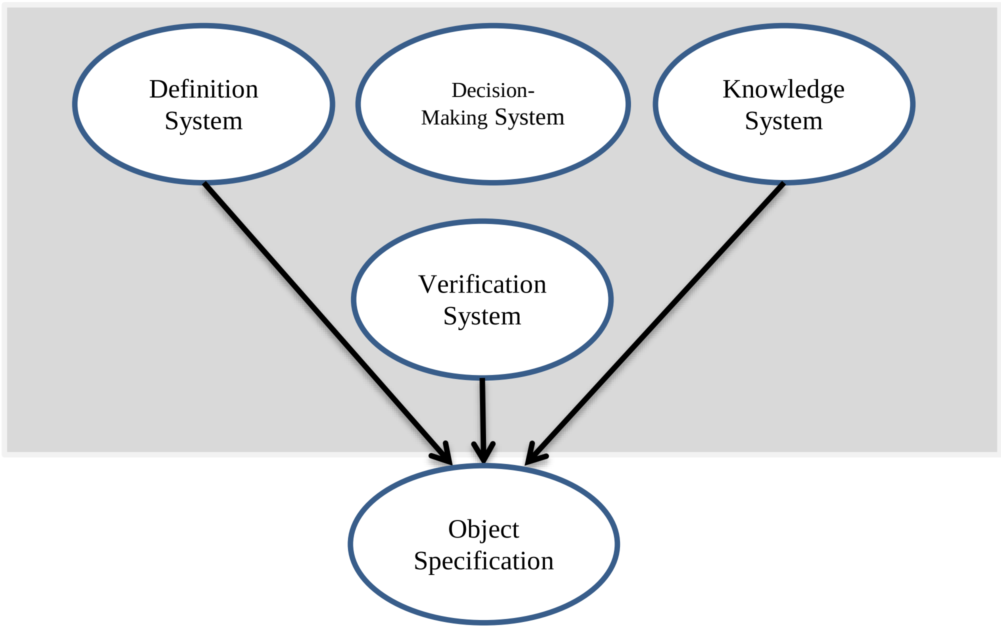

Figure 3. Design Structure scheme

Three sub-systems are particularly relevant to "visualize" the object: the definition systems that include among others, the problem transformed into requirements (what the proposed technological object will solve), structural specification (what the structure of the proposed object), functional specifications (how the object will work) and the ethical issues relevant for this specific technology how it will be avoided to harm people or to respect other human values). The knowledge system includes technological alternatives, availability of scientific knowledge, mathematical and scientific principles relevant to the application, computer tools, ethical themes, and other relevant issues. The verification system includes different tests that will be applied at the different stages of the technological process, including ethical tests to determine the appropriateness of the proposed object according to the ethical requirements previously defined. From these three systems, we obtain a visualization of the object to be produced. Sometimes, prototypes or scalable models are constructed to better understand the properties of the technological object to be developed.

The fourth subsystem, the decision-making system is very important because specifies the human resources involved, the stages in which the product will be developed, how recommendations from the development team will be decided and incorporated into the process, who decides over differences and incompatible recommendations, among other key decisions related to the process and how to keep the integrity of the design.

Following again the analogy drawn from Lakatos, we say that these two approaches to technology (external approaches to technology and technology as a transformation process) are necessary and complementary. Moreover, as I will discuss below a deepening of both perspectives is necessary to make that "no one will be left behind" [9] of the benefits of the fourth Industrial Revolution. But in doing it a change in the conception of technology is needed.

4. Ladriére Perspective on the Impact of Science and Technology on Ethics

As mentioned, Ladriére considers four ways in which science and technology impacted positively on ethics: a) extending the scope of ethics, b) creating new ethical problems, c) suggestion of new ethical values and d) new ways for determining norms. Let us consider each in some detail.

a) **Extending the scope of ethics**. To understand a disease, i.e. Alzheimer, its cause, nosology, and the (neuro) cell and molecular mechanisms involved, has associated a change in the way in which this disease was traditionally explained: as a disease associated with senile dementia, and therefore, something that is related to age and the human has nothing to do to change it. The scientific account of Alzheimer's makes that this approach should be abandoned. But what is more important is that scientific understanding of diseases poses a new imperative: the development of new drugs for treating it or new way of intervening on them, for example, by gene correction therapies, or new medical strategies to prevent its occurrence. Here we see an extension of the scope of ethics because it is imposed as a requirement of intervention for preventing and healing these diseases; this requirement was not present before. Scientists and engineers shall adopt this challenge. Before the development of these interventions, physicians can appeal to god, destination, or "we cannot do more" in case of death. But after the development of medical treatment, physicists are required to justify the claim "we cannot do more" in case of death. The frontier of intervention is extended and new obligations are established. Those new obligations were not presented previously at the introduction of these developments. A second example is the introduction of email for general use in the last decade of the XX century. This changes drastically how we were costumed to consider the mail. Several situations, such as privacy, made that new ethical concerns around the use of email arisen. Regulations to assure the integrity and privacy of the information changed drastically. Not only emerged new ways of organizing the information but new ways of using it. Associated with faster communication and transactions, new forms of espionage emerged; new forms of sabotage, new forms of delinquency, and vulnerability. Society had responded in different ways to reduce the negative impacts of this technology and, at the same time, increase their benefits. An important refreshment of ethical themes was required before establishing new regulations to protect privacy, including the discrimination of the kind of information that should be protected according to the institution or organization. It should be decided if the use of email is restricted or not, and how to protect sensitive information to companies and governments.

b) **Creating new ethical problems**. For Ladriére, science and technology look for different fundamental objectives of those of culture. While science and technology orients to achieve universality, precision, rationality, standardization, tested knowledge and intervention, cultures tend to provide a meaning to life, and tend to be particular; it is the space for constructing personal identity, sense of belonging, and a tendency to conservatism or immutable. Science and technology had invaded society in all aspects, including cultures. New ethical problems that pose science and technology emerge from these contrasting objectives. Two different categories of them emerge, according to Ladriére: internals and externals. Both emerge due to the special position of scientists and technologists. Internal problems concern the nature, structure, and function of science and technology, and its promotion as a socially relevant activity; while externals relate to the social and ethical responsibility of scientists and technologists for the impacts of their developments. Scientists and technologists are in between the two systems and they have to mediate between them. Their mediation consists of determining and guaranteeing the objectives of the society and those of scientific and technological research to make them compatible and as close as possible. But as I will see later, scientists and technologists have their ethical values or the companies for which they work, and these values not always are the same as those of what is desirable for society or culture.

c) **The suggestion of new ethical values**. Directly connected with this topic is the following. The introduction of new scientific and technological results induces a very creative process of proposing new ethical values or reinforce current values to deal with the new conditions. For example, after the introduction to email infrastructure, raised several questions related to privacy issues. Several employees were fired after been accused of emailing private information from their companies [10]. Passionate discussions took place almost everywhere. This process concluded with some important decisions differentiating between those scopes in which emails cannot be checked (inspected) from those in which it is important to do it. In universities, professors and students shall exchange emails freely. In cases of violation of personal integrity, this should be proved in court. In the case of companies, each one has to define a regulatory framework that protects what the company considers important or confidential [11]. In this case, new values emerged connected to privacy, and new rules depending on the different contexts were proposed to make more adequate the use of this important technological development.

d) **New ways for determining norms**. Science and technology are creating a new order over nature that gives to professionals more and more independent to make decisions, not based on traditions or in "nature", but in what is desirable, reasonable, and based on principles. In this way, science and technology are an important source of ethical creativity and rationality. The creation of new norms appropriate to the context makes ethics more rich and complex and ruled by rational criteria. The role that society assigned to science and technology makes this activity the means to gain autonomy and to strengthen human responsibility. It provides more knowledge and tools for intervention; professionals have more and more freedom to decide how to act, at the same time more responsibility for their decisions.

Ladriére´s approach provides an important framework for analyzing the ethical role of scientists, engineers, and technicians concerning how they develop science and technology and also in connection with the impact of scientific and technological achievements on culture and society. We have to indicate that the request for proposing ethical rules to guide scientific and technological development has a large history. But maybe one of the inflection points in this history took place after the construction and dropping of the nuclear bombs on Hiroshima and Nagasaki in August 1945 by the United States. Many scientists, including Heisenberg and others and the Franck Report (1945) [12, 29], provided an important discussion on the issue. Later in 1975 the conference that follows the Asilomar Moratorium (July 1974), after the first successful modification of DNA by Stanley Cohen and Herbert Boyer, provided important ethical guidelines on the use of recombinant- DNA techniques. However, for us, important progress in the implementation of ethical guidelines and rules for technology development came in the latest '80s and the beginning of the ´90s when the two largest engineering associations in the US, the ACM, and IEEE proposed a new curriculum, called "Computing Curricula 1991" for undergraduate programs in computer science and computer engineering. These guidelines are not directly connected with Ladriére proposal of the ethical role of scientists and technologists, but they are consistent with this framework. It was suggested the need to provide students with case analysis and other tools to incorporate the ethical dimension on technology developments in computing.

Following the guidelines proposed in this new curriculum for computing, Chuck Huff and C. Dianne Martin (1995) [13] developed a very interesting methodology for teaching ethics in computer science and computer engineering. That model has three dimensions: the levels of social analysis, in which technological development could directly impact, the social roles of professionals (responsibility dimensions), and the ethical themes. It was framed in the following helpful scheme.

Table 1. Frame for ethical analysis [13]

Technology:										
		Topics of ethical analysis								
		Responsibility		**Ethical themes**						
		Individual	professional	Quality of life	Use of power	Risks and responsibility	Property Rights	Privacy	Equity and access	Honesty and deception
Levels of social Analysis	Individual									
	Communities and groups									
	Organisations									
	Cultures									
	Institutional sectors									
	States									
	Global									

According to Huff and Martin, these seven ethical themes are the most relevant for computing. But not all of them are relevant for specific computing technologies. For example, in digital technologies for health care not always the ethical theme of property rights is relevant. But it is relevant in all cases in which you have to decide to use proprietary software or free software. In any of these cases, the consequences of the decision should be analysed. The dimension of responsibility is particularly important because of the special social position of professionals in this development and in any area of engineering in which they have competence. What is required is that professionals harmonize his/her professional obligations with those values of the larger collectivity at which he or she belongs. In those cases, in which this harmonization is not achievable, a justification of it should be provided. The level of social analysis aimed at making professionals aware that a computer application can have different negative or positive effects on different levels. In some cases, privacy affects directly individuals but also can affect companies, institutional sectors, or cultures. For example, when these companies use private information without consenting from persons. But also, it is important to pay attention to those levels in which a negative affectation can be established, and therefore, he has to make the necessary decisions to eliminate them or to reduce its impact according to the maximum: "As low as reasonably achievable".

So, for each ethical theme and each level of social analysis, it has to be determined the possible negative consequences and to define the measures that should be taken to prevent or reduce these effects. These correlations should be indicated by filling the corresponding boxes. But also, for each filled box, it is necessary to determine if the responsibility for preventing these negative effects can be done by technical means or they also convey responsibilities as individuals. An important principle guides this dimension of responsibility: "You have to clearly understand your professional scope and its limits". The most important decisions concerning ethical issues should be done at the design process, and as indicated, because of its relevance in the subsystems of definition, knowledge, and verification.

This type of analysis represents an important step in the incorporation of the ethical dimension into the technological process. Maybe in other areas of engineering, we may find similar achievements. However, this approach has important limitations. Let us comment on three of them.

One of the most important is that the ethical values of scientists or engineers are diverse. For example, an engineer may consider that developing a new massively destructive weapon is consistent both professionally and individually because he considers that in doing it he contributes to enhancing his nation without considering the possible impacts of this weapon on the rest of the globe. Or that some racial prejudices prevent him to have a wider perspective on his responsibilities as a member of this globe. The need for a multilateral and shared perspective is more important now that we are observing a return of nationalism in several countries worldwide. And at the same time, we are facing a sharpening of global problems such as climate change, the emergence of a new race in massive destructive weapons, including nuclear weapons, global diseases, natural disasters, among others. Niblett (2020) [14] analyses how deep and extended is this nationalism return, affecting almost all world powers, including the United States, United Kingdom, Russia, Hungary, Mexico, Brazil, and India. Other nations, such as South Korea and Japan, he says, react with nationalisms to the threat posed by China. He suggests two way of approaching nationalism: a) by making the international organisations more sensitive to national and local concerns, to promote the legitimacy of these organisations by making "more equitably the voting weights", and avoiding "exceptions and structures that favour the winners of the 20th century" [14]; b) to strengthen the national al local levels to allow that, national governments (…) devolve the maximum amount of political power over social policies, local development and infrastructure to regional authorities, cities or local communities, with corresponding decentralization of some powers of taxation. At a time of technological disruption and rapid economic change, a strong sense of local identity and solidarity can be a more positive force for adaptation than centrally‑driven policies and narratives [14].

The second limitation is that specific interests make that engineers and entrepreneurs consider irrelevant or less relevant other socially important ethical values. Very often economic interest prevails over ethical values and their invasions of privacy or our compromise with truth pass to a second level. On this second limitation, recently Google and Facebook have faced criticisms on how they deal with privacy, discrimination, and the propagation of fake news. These companies have set before economic and competitive interests over these other values with larger consequences on many people around the world. The selling of information from citizens by Facebook to Cambridge Analytica in 2016, has shown us how important are ethical issues, but at the same time that without an appropriate regulation some companies will prioritize economics over ethics. In connection with fake news, public complaints have made that these companies announce a public commitment to avoid the propagation of fake news at these platforms. As will be pointed out, to surpass this limitation, more detailed control on the technological process is needed, including, of course, a control on the product.

The third limitation has a deep root in our own culture. Cultural values are part of the background (unconscious) of scientists and engineers. These are not neutral. As recalled in 2015 Google announced important progress in Artificial Intelligence: the implementation of an algorithm for automatically classify photos considering several features of the photos itself. The problem here was that this algorithm classifies pictures of black people as a gorilla. Program designers "transferred" to the AI algorithm some "cultural values" that explain why the algorithm behaves in that way. And this poses an enormous challenge to the developers of technology to avoid this kind of discrimination. However, the approach to these differences in values should be done considering what has indicated by "Qi Zhenhong, President of the China Institute of International Studies" who "makes the case that global frictions – particularly those between the West and non-West – are largely the result of values‑based alliances that have served to exaggerate differences between cultures." [15].

The mentioned limitations open the door to introduce the ethical challenges we are facing in the context of the fourth industrial revolution. But before doing it, we have to provide some background on how technology is currently discussed in that context.

5. Technology in the Context of the Fourth Industrial Revolution

In the first section, I introduced two general perspectives on technology. The first called "externalist" emphasizes the impact of technology in society, how this world changed driven in great part due to technology, and how matter, energy, and information are operationally transformed to obtain a variety of technological products. And so on. But also, I introduced a more "internalist" process of technological development organized in several steps and loops. In the fourth industrial revolution, we need both perspectives but with a level of integration and deepening never seen before.

Schwab (2016) [16] made a similar identification of domains as Papa-Blanco (1979) [2] did, labeling them: the physical, the digital, and the biological. The physical includes the trends that we are observing, such as different kinds of autonomous vehicles, developments in nanotechnology, new materials, advanced robots, and 3D printing. The digital includes the trends in new satellite communication, 5G technology, quantum computing, Artificial Intelligence, and the different technologies associated, such as the Internet of Things, Block chain, and the new modalities of e-commerce. On the biological domain the gene sequencing, gene edition, cell stem, and synthetic genetics. However, one of the novelties of this fourth industrial revolution is the integration of these systems to produce a richer, more diverse, and intense process of technological development:

> The fourth industrial revolution, however, is not only about smart and connected machines and systems. Its scope is much wider. Occurring simultaneously are waves of further breakthroughs in areas ranging from sequencing to nanotechnology, from renewables to quantum computing. It is the fusion of these technologies and their interaction across the physical, digital, and biological domains that make the fourth industrial revolution fundamentally different from previous revolutions [16].

In the same vein, Philbeck and Davis (2019) [17], referring to this revolution (4IR), indicate:

> The layering of dependencies matters because it shows that 4IR is best suited to examining technologies and systems that take the digital world for granted. Today, the combination of powerful machine-learning algorithms, low-cost sensors, and advanced actuators are allowing technologies to be seamlessly embedded into our physical environment. Furthermore, when combined with advanced imaging, signal processing, and gene-editing approaches, they have the potential to influence our physiological condition and cognitive faculties. Digital technologies are part of the fabric of daily life and, as they give rise to a new layer of physical and biological technologies, it is paramount to consider the ways that newer technologies emerging atop them are extending capabilities beyond the immediate functionality of being able to transmit, store, and process exponentially greater amounts of data [17].

So, one of the new features that present this industrial revolution is its integration of the three mentioned systems. We assisted to some degree of integration in satellites and the infrastructure of communication, but in this revolution, the integration will be unprecedented. Integration should be thought of as a continuous scale from weak integration to strong integration. Several intermediate stages of integration will be achieved.

Weak integration means that the introduction of technology poses new challenges to other technologies and vice-versa. For example, the construction of cars requires that the routes to circulate be improved, new light systems to regulate the traffic need to be adjusted, and a new signal system for the drivers was also developed; and new transportation means are also needed. It is expected that, in medicine, weak and strong integration be an important part of the system of health. The use of robots in assisting the surgery process, screens with augmented reality, remote access technology will help the team in charge of surgeries. But also, more strong integration is needed and will take place. We achieve more integration, for example, when a central command (a computer program or human team) centralizes different processes, such as the coordination of patient transportation system, medical assistance during the transportation of patients, reading of biometric data, and intervention and the surgery team. In this case, the centralization of the control of the process adds an important degree of integration not achievable in the other mentioned example.

In connection to the changes in health and healthcare, I would like to briefly mention two interesting studies. The first one, WEF-GFC (2019) [18], evaluates the changes in these two areas in the years 2016-2018 aimed at getting new insights on the future transformation of health and healthcare in the context of the fourth industrial revolution. Three main trends are considered here: a) demographic changes worldwide and the pressure posed on health services; b) the fall down in costs in genome sequencing and other related biotechnological techniques of great impact in health; and c) the expected impact of new technologies on health and healthcare, including "internet of things (IoT), wearables, sensors, big data, artificial intelligence (AI), augmented reality (AR), nanotechnology, robotics, and 3D printing". In the second study, Khedkar and Sahay (2019) [19], have included five main trends in healthcare that results from the integration of biotechnology and information technologies (IT), especially Artificial Intelligence: a) remote or telemedicine, as a consequence of the penetration of IT, b) more precision in the diagnosis and treatment of diseases due to an extraordinary increase in the individual information available for decision making, c) a more intensive recourse "to design custom products for biomarker-tagged populations" to make more targeting diagnosis and treatments; d) customer's new tools "for transparency are making it feasible for consumers to demand metrics on provider quality and price"; and e) changes in the traditional model of business toward a more integrated and customer-oriented. Direct impacts will be observed in diagnostic, treatment, outcome, and wellness processes.

The second feature related to the fourth industrial revolution is the pace of development of technology, incomparable with that of the previous revolutions. However, we see some continuity from a very slow pace of the first revolution that took regenerations to progress, to the third industrial revolution that took only one generation. The fourth industrial revolution will be very fast, as shown in the example of Shenzhen, China, that in only ten years was almost radically changed: it was transformed from a village to one of the most important centers of innovation worldwide. Bulanda-Jansen (2019) [20], has studied briefly the evolution of Shenzhen, its two plans: 1996-2010 and 2010-2020. It was the second plan that has reconfigured the city. This pace of transforming a city poses additional problems that she enlisted, including neglecting social aspects, not appropriate control of migration, inadequate legal and policy control and, an increase in pollution, among others. Much will be learned from these experiences to face our future.

One-third feature of this revolution, related in part with the pace of change, is its disruptive character. Many jobs currently existent and practices will become obsolete in a matter of years. As pointed out in the last report of the World Bank, "The days of staying in one job, or with one company, for decades are waning. In the gig economy, workers will likely have many gigs over the course of their careers, which means they will have to be lifelong learners.". In the same line, the report "The future of Jobs" of the World Economic Forum (WEF), it is claimed: "By one popular estimate, 65% of children entering primary school today will ultimately end up working in completely new job types that don't yet exist." [21].

The fourth feature of this revolution is the dramatic change in the role of innovation. In the preceding revolutions, innovation was directly related to capital. The capital was very important to achieve innovation. Every day capital is becoming less relevant, at least at the beginning. The most innovative companies today have started with very little capital. On this, Schwab (2016) points out: "Some disruptive tech companies seem to require little capital to prosper. Businesses such as Instagram or WhatsApp, for example, did not require much funding to start up, changing the role of capital and scaling business in the context of the fourth industrial revolution [16].

The use of technological infrastructure currently available worldwide is becoming an important source of innovation. Because of this, governments have to invest in those platform technologies that have the potential to increase innovation. This change has made that one of the bigger problems be, to push the cultural change to allow that more people have opportunities for innovating.

The fifth feature is the development of technological constellations to respond to political and geopolitical interests. We observe it in the different global satellite navigation systems with different objectives, the launching of cryptocurrencies as a strategy to guarantee a better global position of the economic blocks. But this feature is not inherent to the fourth industrial revolution as are the others.

From an internalist perspective, that is, from the technological process, the fourth industrial revolution is showing an important feature. The development of technology is becoming every day more and more a closed system. Standards, protocols, and specific specifications are required to make that the new development be consistent with existing infrastructure or with the new one. Let consider, IoT. Currently, it is important to advance in the development of interfaces and other standards to potentiate the spreading of these platforms and application domains. W3C (WWW Consortium), has among other purposes:

> The W3C Web of Things (WoT) is intended to enable interoperability across IoT Platforms and application domains. Primarily, it provides mechanisms to formally describe IoT interfaces to allow IoT devices and services to communicate with each other, independent of their underlying implementation, and across multiple networking protocols. Secondarily, it provides a standardized way to define and program IoT behavior [22].

This tendency will be increased shortly driven by requirements of interoperability, consistency among applications, platforms, and integration. I think this is one of the main features we will be consolidated in the coming years.

However, it is expected another fundamental feature of technology in this fourth industrial revolution: It will be systemic. This is not limited to the integration of different technologies at the level of constellation and integration between these constellations, diverse technologies, and contexts, but the challenge is to make this revolution a source of welfare and quality of life. Human factors are determinant for the success of this revolution. How to do this, is complex and uncertain, but it will find the way. As pointed out by Schwab:

> While the profound uncertainty surrounding the development and adoption of emerging technologies means that we do not yet know how the transformations driven by this industrial revolution will unfold, their complexity and interconnectedness across sectors imply that all stakeholders of global society – governments, business, academia, and civil society – have a responsibility to work together to better understand the emerging trends [16].

So, we have to assure that this revolution makes true that "nobody will be left behind". To accomplish it, this revolution must be centralized in human beings and the environment. To quote again Schwab:

> Shaping the fourth industrial revolution to ensure that it is empowering and human-centred, rather than divisive and dehumanizing, is not a task for any single stakeholder or sector or any one region, industry, or culture. The fundamental and global nature of this revolution means it will affect and be influenced by all countries, economies, sectors, and people. It is, therefore, critical that we invest attention and energy in multi-stakeholder cooperation across academic, social, political, national, and industry boundaries. These interactions and collaborations are needed to create positive, common, and hope-filled narratives, enabling individuals and groups from all parts of the world to participate in, and benefit from, the ongoing transformations [16].

Some systemic nature of technology was also present in the previous industrial revolutions. But it is now that we are aware of the need of having this approach from the beginning. In the White Paper *Values, Ethics and Innovation* (2018) [23] the World Economic Forum, illustrates this systemic feature of technology. Let me quote in extension this example:

> Take the automobile, for example. At the turn of the 20th century, vehicles powered by steam, electric, or internal combustion engines that could run on gasoline or biofuel all looked to be potential alternatives to horse-drawn vehicles. Gasoline-powered vehicles gradually reached a socially transformative scale due to a wide system of

aligned interests, visions, technological advances, investments, business models, and political support. As this system became entrenched, it directed and constrained choices, incentivizing technologists to focus efforts on improving gasoline engines rather than on innovating in steam- or electric-powered transport. This "lock-in" has long-lasting effects and constrains problem-solving as systems develop.

The automobile opened and closed choices in other, broader ways. Widespread car ownership conferred greater personal autonomy, for example, but led to the design of cities that were challenging to navigate on foot, by bicycle, or by public transport. It enabled suburban sprawl, with attractive individual places to live but ways of life that arguably eroded social cohesion. Moreover, this development contributed to deep economic dependence on oil and to the pollution that has severe health and environmental consequences, including impacting climate change. None of these impacts were inevitable; they were mediated by collective choices, such as tax incentives and the relative priority placed on building roads or mass transit systems.

Technologies impact entire systems – economic, social, and political. They shape world views, and world views shape them as well. They are dreamed up and refined in laboratories and workshops by teams of people. Their development, just as anything else, is subject to social factors, such as tribalism, water-cooler politics, and gender discrimination. A systemic view of how values and ethics become part of the technological development process is needed [23].

6. Sustainable Development as a Framework for Shaping the Fourth Industrial Revolution

Human sustainable development was launched during the first half of the '90s as an alternative to the dominant conception of development based on the market [24]. This change of position took place after the events that culminate with the segregation of several countries part of the former USSR, ending with a phase of the cold war and opening the door to multilateralism, a process in march currently. Of course, this new paradigm has historical antecedents, particularly in philosophy. For example, but not limited to the German philosophy of romanticism. Kant made of autonomy the foundation of modern states. Autonomy should be understood as supported by five "faculties": freedom, responsibility, formation (Bildung in German), information, and no-coercion. Kant and other philosophers (Fichte, Schelling, Hegel) conceived societies and states as territories formed by free (autonomous) citizens [25]. Freedom rests on and influences the other autonomic components. The goal of states is to promote autonomy as the way of overcoming the need and want of individual in his supposed “natural state”.

Autonomous ethics implies that good and bad, justice and injustice are evident by itself [26]. We can conclusively infer if autonomy was violated in a specific situation or not. It is not necessary to do a "consequence" analysis to determine the good or bad involved in human action. This fact makes other thinkers questioned autonomy as the goal of the state. In this important stage of the consolidation of national states, Jeremy Bentham (1748-1832), John Stuart Mill (1806-1873) and Henry Sidgwick (1938-1900) proposed and defended that the role of the state is to promote and accomplish the happiness of people. It should provide tools for determining conditions under which “more happiness” is achieved. Consequence analysis is the key for the state to planning its development and measuring its progress. Classical consequentialism made the radical claim that in the evaluation of the consequences of an action, intentions are not relevant to decide if an action is good or not [27]. Good results from analyzing the consequences of the action. Contrary to it, for autonomous ethics agent intentions are relevant to determine if people are treating the others as ends or as mere means.

In human sustainable development, both ethical perspectives are relevant. Autonomy and its distinction between means and ends provide the ultimate goal of development: to make human beings the center of development; it should be human-centered development. The means (and intentions) and its consequences are also relevant to achieve and measure the development. Education, human security, and work with dignity for everyone are indispensable means to achieve this development. But human sustainable development includes another centralized goal: the protection of the environment.

The General Assembly of United Nations adopted in 2015, by all the state members, the resolution A/RES/70/1 [9] that establishes the vision, goals, and the new agenda for the coming 15 years (2015-2030). It was the first time in the history that all the state parties agreed on this global agenda. This resolution is, what we may call, a new “social contract” in which all of us are called to work together to achieve the agenda. It will permit us to shape the fourth industrial revolution to make that this revolution will be at the service of human beings and to the protection of the environment. In this agenda, it was put at the same footing five key “areas” for “humanity and the planet”: persons, planet, prosperity, peace, and partnership. The 17 goals and the 167 targets express how these are integrated and should be implemented. This agenda poses a tremendous challenge for humanity and urges us to work together to achieve it.

In the vision proposed it is emphasized on three elements [9]:

1. Elimination of fear and violence: "We envisage a world free of fear and violence. A world with universal literacy. A world with equitable and universal access to quality education at all levels, to health care and social protection, where physical, mental, and social wellbeing are assured. A world where we reaffirm our commitments regarding the human right to safe drinking water and sanitation and where there is improved hygiene; and where food is sufficient, safe, affordable, and nutritious. A world where human habitats are safe, resilient, and sustainable and where there is universal access to affordable, reliable, and sustainable energy."
2. Effective fulfillment of individual, social, and cultural rights, especially concerning more vulnerable social groups. "We envisage a world of universal respect for human rights and human dignity, the rule of law, justice, equality, and non-discrimination; of respect for race, ethnicity and cultural diversity; and equal opportunity permitting the full realization of human potential and contributing to shared prosperity. A world that invests in its children and in which every child grows up free from violence and exploitation. A world in which every woman and girl enjoys full gender equality and all legal, social, and economic barriers to their empowerment have been removed. A just, equitable, tolerant, open and socially inclusive world in which the needs of the most vulnerable are met."
3. A development guided by good governance and protection of the environment. "We envisage a world in which every country enjoys sustained, inclusive, and sustainable Economic growth and decent work for all. A world in which consumption and production patterns and use of all-natural resources—from air to land, from rivers, lakes, and aquifers to oceans and seas — are sustainable. One in which democracy, good governance, and the rule of law, as well as an enabling environment at the national and international levels, are essential for sustainable development, including sustained and inclusive economic growth, social development, environmental protection, and the eradication of poverty and hunger. One in which development and the application of technology are climate-sensitive, respect biodiversity and are resilient. One in which humanity lives in harmony with nature and in which wildlife and other living species are protected."

As pointed out, 17 sustainable development goals are proposed to achieve in 2030. These goals form a system, they should be taken as a harmonic totality, including the viewpoint and areas that give structure to them; though each country can select and prioritize some of them. Different ethical values can be derived from them and taken as starting points for the development of methodologies to be used as guidelines for this fourth industrial revolution. As recalled, these 17 goals include the following relevant social, economic, institutional, and environmental themes: end of poverty, end of hungry, healthy lives for everybody, equity, and social inclusion, education of quality, women empower, water and sanitation for all, inclusive and sustainable economic growth, resilient infrastructure for foster innovation, reduce inequality among countries, sustainable cities and human settlements, sustainable consumption, combat to climate change and its impacts, protection of oceans and seas, sustainable use of terrestrial ecosystems, peace and inclusive societies and, finally, global partnership.

Particularly relevant to our approach is the goal 17, "Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development" and the "Means of implementation and the Global Partnership". The goal divides into 19 targets on different issues relevant to achieving the goal, in the areas of finance, technology, capacity building, trade, systemic issues, multi-stakeholder partnerships, data, monitor, and accountability. And the means of implementation introduces several strategies and actions to implement this global partnership. Among them, specific programs for Africa, cooperation for middle-income countries to overcome the identified challenges, domestic investment in the environment, the protection of labor rights and work conditions, health standards, promotion of trade and companies, and the Technology Facilitation Mechanism established by Addis Ababa Action Agenda, but added as a structural part in this partnership agenda.

As observed, all these themes are especially relevant for the fourth industrial revolution. However, I want to emphasize the relevance of multi-stakeholder partnership and the Technology Facilitation Mechanism because these are directly involved in the way in which it is discussed worldwide the shaping of the fourth industrial revolution towards a trustworthy framework for human and environmental centrality. Multi-stakeholder partnerships and the Technology Facilitation Mechanism include the important component of capacity-building needed to accomplish this agenda.

Let me introduce briefly two approaches that emphasize, among other things, on the important role of multi-stakeholder partnership to assure that the fourth industrial revolution should be at the service of the human being and the protection of the environment. The first one is the White Paper (2018) from WEF [23, 30], and the second, the Guidelines for Trustworthy Artificial Intelligence (AI) (2019) [28]. Let´s start with the second one.

European Union set up a group of experts, the "High-Level Expert Group on Artificial Intelligence" with the task of proposing a framework from promoting and regulating AI within the European Union. As indicated in the report:

> The Guidelines aim to promote Trustworthy AI. Trustworthy AI has three components, which should be met throughout the system's entire life cycle: (1) it should be lawful, complying with all applicable laws and regulations (2) it should be ethical, ensuring adherence to ethical principles and values, and (3) it should be robust,

> both from a technical and social perspective since, even with good intentions, AI systems can cause unintentional harm. Each component in itself is necessary but not sufficient for the achievement of Trustworthy AI. Ideally, all three components work in harmony and overlap in their operation. If in practice, tensions arise between these components, society should endeavor to align them [28].

These guidelines will receive a final review this December. So, the definite version of them will be available at the beginning of the next year. Readers will find there an interesting approach to the application of ethics to the development, deployment, and use of AI within the European Union. This framework lays out taking as starting points the following four ethical preventive principles: "respect for human autonomy, prevention of harm, fairness, and explicability". From these, like a cascade, seven requirements are segregated: "(1) human agency and oversight, (2) technical robustness and safety, (3) privacy and data governance, (4) transparency, (5) diversity, non-discrimination and fairness, (6) environmental and societal well-being and (7) accountability". From these, "(a)dopt a Trustworthy AI assessment list when developing, deploying or using AI systems, and adapt it to the specific use case in which the system is being applied." [28].

What is of interest to us is the third requirement for trustworthy AI: It should be robust. This implies working in solving several relevant issues from legal, development, and institutional. Legal requires that these trustworthy guidelines be "anchored" naturally in the European Union regulatory system in such a way that it makes it easier to foster this research area. But at the same time, it should be consistent with the culture and values of the European Union. Developers need to have clear rules and guidelines on how to proceed in every planned development in which AI plays an important role. Finally, institutionally it is needed to have an institutional structure that makes transparent the development, deployment, and use of AI. This institutional structure should, at the same time, have a place within the regulatory system, aimed at guarantying transparency and traceability. One key component of this institutional structure is the multi-stakeholder sub-structure in which each stakeholder group has a specific role to play in assuring the fulfillment of the four promoted and preventive ethical principles mentioned above.

Institutional structures are not strange currently. The process of research, development, testing, and commercialization of drugs has a very rigorous and well-established structure. For AI development, deployment and use will be the same, but I think more flexible and with shorter periods. In this proposal several stakeholders are involved in the process:

> These guidelines are addressed to all AI stakeholders designing, developing, deploying, implementing, using or being affected by AI, including but not limited to companies, organisations, researchers, public services, government agencies, institutions, civil society organisations, individuals, workers, and consumers." [28].

These Guidelines provide several examples of how to achieve ethical principles and requirements. Let us illustrate with the issue of "human oversight" as presented in the document.

> Human oversight helps to ensure that an AI system does not undermine human autonomy or causes other adverse effects. Oversight may be achieved through governance mechanisms such as a human-in-the-loop (HITL), human-on-the-loop (HOTL), or human-in-command (HIC) approach. HITL refers to the capability for human intervention in every decision cycle of the system, which in many cases is neither possible nor desirable. HOTL refers to the capability for human intervention during the design cycle of the system and monitoring the system's operation. HIC refers to the capability to oversee the overall activity of the AI system (including its broader economic, societal, legal, and ethical impact) and the ability to decide when and how to use the system in any particular situation. This can include the decision not to use an AI system in a particular situation, to establish levels of human discretion during the use of the system, or to ensure the ability to override a decision made by a system. Moreover, it must be ensured that public enforcers can exercise oversight in line with their mandate. Oversight mechanisms can be required in varying degrees to support other safety and control measures, depending on the AI system's application area and potential risk. All other things being equal, the less oversight a human can exercise over an AI system, the more extensive testing and stricter governance is required [28].

As indicated the strictness of testing is directly related to the kind of human oversight exercised. Developers should include restrictions and conditions for use of AI applications in different contexts, and the other stakeholders should verify the accomplishment of them. Special conditions should be met in those cases in which potential discriminations could happen. What is interesting here is that standards and protocols will be implemented to facilitate the verification process and, to assure that human and environmental centrality will be respected.

In a similar vein, the White Paper of the WEF [23] argues for the need of this diverse and wide stakeholder partnership to assure that the ethical values of people, cultures, and innovation capabilities are expressed in this fourth industrial revolution. This implies the development of strategies for solving the problem of the diverse criteria, perspectives, and values that are proper in heterogeneous groups. But it is a constructive process in which all countries, companies, institutions, and citizens should be engaged. This paper visualizes the following stakeholders are relevant in this revolution: Civic leaders and citizens, consumers, engineers, executives, Boards, policy-makers, and educators. All of them shall contribute and reach a consensus in the shaping of the fourth industrial revolution.

Both documents are rich in ideas and proposals on how to make that science and technology, and this revolution can be at the service of the welfare of humanity and the protection of the environment. In paragraph 70 of the resolution, A/RES/70/1 of the United Nations introduced the "Technology Facilitation Mechanism" aiming at providing a structure for sharing and promoting the development of technologies according to vision, goals, and targets agreed in this agenda. This proposal is particularly relevant for shaping the fourth industrial revolution. The statement of this mechanism is the following:

> We hereby launch a Technology Facilitation Mechanism which was established by the Addis Ababa Action Agenda to support the Sustainable Development Goals. The Technology Facilitation Mechanism will be based on a multi-stakeholder collaboration Between Member States, civil society, the private sector, the scientific community, United Nations entities, and other stakeholders and will be composed of a United Nations inter-agency task team on science, technology, and innovation for the Sustainable Development Goals, a collaborative multi-stakeholder forum on science, technology, and innovation for the Sustainable Development Goals and an online platform [9].

Three main orientations are proposed to advance in the deployment this goal: a) an infrastructure for capacity building within the United Nation Organisations; b) “The multi-stakeholder forum on science, technology and innovation for the Sustainable Development Goals”, and c) Meetings of the high-level political forum to assess progress and to draw agenda.

I have emphasized multi-stakeholder partnership because its implementation will change, in a radical way, our conception of technology, and it will yield technologies closer to society's needs. Let me end this paper with some general consideration on this issue. I will follow the analysis presented in the White Paper above mentioned.

In the previous sections of this paper, I discussed two different approaches to technology. The first one pays attention to products generated as a result of technological research and to shed a different light on the deployment of technology in society, culture, and environment. The other mentioned approach, called "technological process" emphasized the internal structure of technology that makes possible the tremendous impact of technology in our world. As pointed out in the White Paper, these perspectives are not appropriate to understand the kind of technology we have to shape in this revolution [31-33].

> The first widespread perspective approaches technologies as mere tools that are intrinsically and unquestionably aligned with greater opportunity. The second prevalent view regards history as driven by technological progress, with people powerless to shape its direction: in this view, technologies are inevitable and out of human control. Neither of these views, though pervasive, is ideal nor fully accurate.
>
> The lack of a more critical comprehension of technologies, and their moral role in society, reduce our ability to make informed decisions about the development and application of powerful new approaches, particularly with those technologies that blur the lines between human and technological capabilities, such as machine learning, biotechnologies, neuro-technologies, and virtual and augmented reality.
>
> A more balanced and empowering perspective recognizes technologies as capabilities that interpret, transform, and make meaning in the world around us. Rather than being simple objects or processes that are distinct from human beings, they are deeply socially constructed, culturally situated, and reflective of societal values. They are how we engage with the world around us. They affect how people order their lives, interact with one another, and see themselves. Far from an academic observation, this more nuanced view has practical importance for strategic needs as well as implications for the successful governance of technologies [23].

It is in this way that we have to march in the shaping of the fourth industrial revolution. We have the opportunity to make that this revolution contributes to achieving the objective of making that "nobody will be left behind" of the benefit of this revolution.

7. Conclusion

To summarize, important signs of progress were made regarding the role that ethics played in science and technology had during the last 50 years. However, the most revolutionary change we will assist in the efforts that we are making to assure that ethics shapes the future of the fourth industrial revolution aiming at benefiting everybody worldwide, creating a better world for anyone, and advancing in environmental protection. United Nation resolution on SDG is taking as a base to promote and achieve these goals. Technology should be molded by human values and should be enriched from different cultural perspectives.

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9. Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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