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The role of big data and cognitive computing in the learning process

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ABSTRACT

In this paper, we investigate how the raise of big data and cognitive computing systems is going to redesign the labor market, also impacting on the learning processes. In this respect, we make reference to higher education and we depict a model of a smart university, which relies on the concepts that are at the basis of the novel smart-cities' development trends. Thus, we regard education as a process so that we can find specific issues to solve to overcome existing criticisms, and provide some suggestions on how to enhance universities' performances. We highlight inputs, outputs, and dependencies in a block diagram, and we propose a solution built on a new paradigm called smarter-university, in which knowledge grows rapidly, is easy to share, and is regarded as a common heritage of both teachers and students. Among the others, a paramount consequence is that there is a growing demand for competences and skills that recall the so called T-shape model and we observe that this is pushing the education system to include a blend of disciplines in the curriculums of their courses. In this overview, among the wide variety of recent innovations, we focus our attention on cognitive computing systems and on the exploitation of big data, that we expect to further accelerate the refurbishment process of the key components of the knowledge society and universities as well.

1. Introduction

Nowadays, people, computers, smart devices, appliances and objects are connected each other in a large and very complex information-driven eco system. In fact, due to the many enabling technologies, social phenomena and economic factors such as (i) the continuous advancements in electronics, (ii) the ever-growing computing power of microprocessors, (iii) the availability of fast and large memory supports at affordable costs, (iv) the prompted miniaturization, (v) the compelling innovation in network infrastructures and networking, a huge amount of data springs from a variety of different sources and is spread at dramatically high speed. This happens in novel settings with less and less boundaries, which drive to the definition of new reference models as well as new standards of services. Accordingly, as stated by Brynjolfsson and McAfee [1], we are living the dawn of the second machine age. An era in which we can attend the evolution of astonishing machines, which are able to surprise us for their capabilities, and that we could not even envisage a few decades ago. Such machines are the ones that will drive the economy of this century and they will not stop evolving because *"the exponential, digital, and recombinant powers of the second machine age have made possible for the human to create two of the most important one-time events in our history: the emergency of real, useful artificial intelligence (AI) and the connection of most of the people on the planet via a common digital network. [..] In this new age we care more about ideas not things, minds not matter, bits not atoms, interactions not transactions, [..] which call for new organizational structures, new skills, new institutions, and perhaps even a reassessment of our values."* An immediate consequence deriving from the introduction of such machines is that new skills are required to manage them suitably.

Besides, Brynjolfsson and McAfee also specify that *"technology like big data and analytics, high speed communications and rapid prototyping have augmented the contributions made by more abstract and data-driven reasoning and, in turn, have increased the value of people with the right engineering, creative, or design skills."* In a few words, there is an increased demand for skilled labor and this demand will be stable, or even growing, in the years to come. Also many economists have confirmed this trend and they called it the *"skill biased technical change"* [2], which favors people with more human capital. In this context, it looks self-evident that education has a paramount role, more than ever before. In particular, the need of T-Shaped professionals is widely recognized as a *stimulus* for the services science, rather than a mere industrial need [3]. The molding of such T-shaped people can only be achieved by putting together two different types of competences:

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(1) the *stem* of the T, a specific and strongly domain-dependent *bouquet* of deep competences, which represent the mastery in any field of study, discipline, or application;
(2) the *arm* of the T, horizontal competences, which outline the individuals' ability to move abroad the other complementary capabilities (such as, e.g., project management, communication, organizational culture, critical thinking, teamwork, networks, etc.).

In this wide and very complex scenario, in this paper we make specific reference to higher education and try to guess which are the evolutions that we can expect and that will be well established on a short-term horizon. To this aim, we rely

on results already published in a previous work, in which we identified the main drivers for universities' empowerment, to be able to draw the reference model of a "smarter university" [4]. It is worthwhile recalling that we decided to use *smarter* in place of the more common and widely adopted *smart* because, generally speaking, today's universities widely adopt cutting-edge technologies and systems and this is sufficient to make them some smart universities. However, we argue that this is not enough and that they should make a further step ahead, in the direction of the "smarter" model, to enhance their effectiveness and improve their performance indexes, as well as achieving higher position in international ratings. Furthermore, in this way universities will be more flexible and they will develop the ability to seamlessly adapt to novel and emerging society needs, which are very fast changing and to face effectively modern challenges such as expanding access to all levels of education, enhancing lifelong learning, and facilitating non-formal education.

Then, we consider new issues recently emerged, by keeping into account novel research trends that are gaining consensus in the scientific community and that we expect will have a prominent role in the very next future, such as: (i) the availability of big open data coming from software applications and sensors, coupled with the ability to effectively manage them by means of suited techniques, analysis tools, methodologies, and storage systems; (ii) the wide diffusion of systems based on cognitive computing principles, which can interact with humans in an innovative way, thus fostering collaboration among people and machines and the adoption of innovative decision strategies as well as personalized support systems for many fields of application, ranging from health to education.

In addition, since we report results from specific experiences carried on at software engineering classes, we also consider the benefits deriving from: (iii) the use of a cloud-based computing infrastructure; (iv) the use of a development environment based on the Platform-as-a-Service (PaaS) paradigm, which affected positively the learning outcomes, at least for technical education.

The remainder of the paper is organized as follows. In Section 2 we recall the smarter university model and, in Section 3, we make some general considerations about it, based on the outcome of a project and the relevant data, including results achieved. Then, in Section 4 we analyze the modifications introduced by big data and cognitive systems while, in Section 5, we focus on the skills produced by smarter universities. Finally, the Section 6 on conclusions and future works close the paper.

2. The smarter university model

As already mentioned, in our previous research we have recognized the need of a significant change in education and we have proposed the model of a Smarter University, which is depicted in Fig. 1 and that we are going to recall. The process is made up of several steps, which are described in more details in the following:

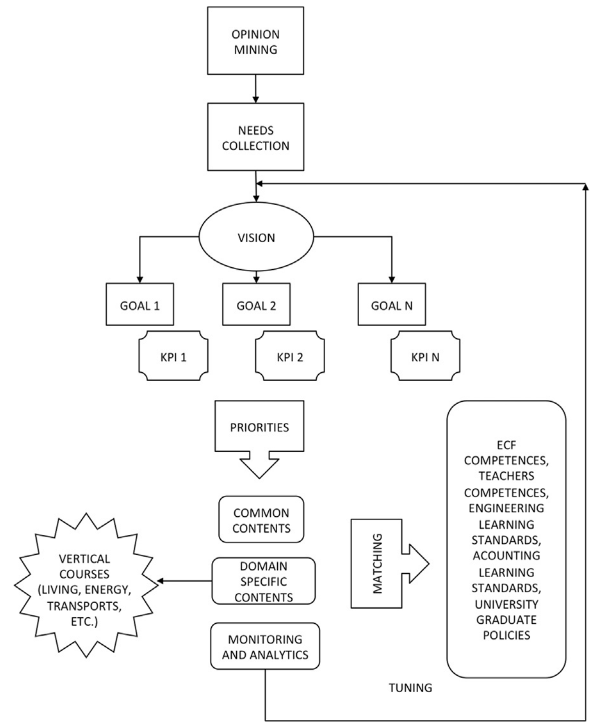

Fig. 1. The smarter university model (borrowed from [4]).

2.1. Opinion mining

The first step of the process requires collecting different opinions, which will be later organized and structured.

2.2. Needs collection

The second phase of the proposed model corresponds to an in-depth analysis of the needs emerging from the area, the communities and the organizations. In this step, the collected views are organized and structured according to their sources (stakeholders). These views are then translated into specifications and constraints of the system.

2.3. Vision

The presence of multiple variables and constraints encourages the creation of a strategic vision that must be translated into clear objectives, ambitious yet realistic. The objectives should clearly state the expected achievements in the medium and long term. Therefore, the strategic vision is structured with measurable objectives, a set of goals ***G***, where

$$G = \{Goal_1, \quad Goal_2, \quad \ldots, \quad Goal_N\} \tag{1}$$

whose reach is measured through Key Performance Indicators (KPIs) in ***K***, where

$$K = \{KPI_1, \quad KPI_2, \quad \ldots, \quad KPI_N\} \tag{2}$$

is the set of relevant KPIs. The goals are to be constantly monitored and the associated KPIs allow measuring the degree of achievement for each goal. A corrective action accompanies the monitoring and measurement activities and is used to steer the objectives of the system when necessary. At this stage, we can adopt a metric plan based on the Goal Question Metrics (GQM) model [5].

2.4. Priorities

The above mentioned objectives are then ordered as a two-dimensional array according to their priority and their measure of urgency. Specifically, higher priority goals are implemented first; lesser priority and less urgent ones follow. Goals with low priority and non-urgent goals can be excluded.

2.5. Common contents

The model extracts common contents, knowledge and skills that an individual must have in multiple scientific areas, which correspond to the transverse part of T-shaped people.

2.6. Domain specific contents

The vertical part of the T is represented by the knowledge and the skills that individuals must possess in a specific domain. For these domain-specific contents suited *vertical courses* are identified. In practice, at this stage the creation of multi-domain contents should be taken into account as well.

2.7. Competences, standards and policies

On the right side of the model depicted in Fig. 1, the competencies are described, e.g., in the ECF (European e-Competence Framework) for ICT Professionals in all industry sectors, and teachers' skills are taken into account.

2.8. Matching

One of the most challenging parts of the model is the task of matching the choices with the needs. The complexity is not only due to the presence of requirements imposed by outside the system, but also due to the feasibility of the actions defined in the higher parts of the model. For example, it may happen that the professional figures identified by the model cannot be realized simply because there are no teachers with appropriate knowledge available.

2.9. Monitoring and analytics

The proposed model provides an abstract representation of a vision. Its application to specific situations and environments requires the implementation of a specific structuring of each part and such a process that can be very complex. It must also be said that this model requires the help of various tools such as forecasting, simulation, data collection and analytic tools. The monitoring and data collection must be implemented in such a way that it initially performs analysis on the data collected during the trial implementation of the process and successively uses the result of the analysis to make adjustments on the process model to adapt to the needs of the system.

Accordingly, the presented vision of a smarter university is the vision of the future university, which responds to the students' needs in a sustainable, social and technological way. In particular, social aspects include the use of data gathered from social network sites and it is mandatory to consider the relevant privacy problems and security issues (for a detailed analysis see [6] and references therein, while a possible solution is hinted in [7,8]). Moreover, the development of higher education can rely on satellite communications too to deliver material and videos, which can enable millions of students in rural areas and developing countries to receive the education they deserve (see, e.g., [9] for general aspects and a performance evaluation of the SPDY protocol for transporting web content). Besides, it is worthwhile noticing that "being smart" should not be confused with "being digital". In fact, the ICT infrastructures are the means, not the end, enabling a set of services that affect deeply the life of the university [10]. For example, the availability of broadband as a resource is essential to ensure that business is more competitive and to reduce the digital divide between citizens; the availability of low-frequency short-range technologies represent an essential resource for enabling the development of the IoT [11,12], as well as semantic technologies (see [13] and references therein for an example of their use in education). Similarly, Wi-Fi and cloud technologies provide a valuable tool for reaching high-frequency strategic areas such as laboratories, libraries, meeting points, and so on. Of course, wherever the interconnection of these technologies is available, it might be possible to have an effective and timely monitoring, as well as a constant update, of each student's part of the vision.

3. Pondering over the smarter university model

While looking at the current model of the smarter university, we look for the match with the major elements that are speeding up the knowledge acquisition process.

3.1. Elements that accelerate the knowledge acquisition

In order to validate the proposed smarter university model, we carried on a set of experiments during our daily teaching activities. More in details, the results achieved in past experimental pursuits (duly described in [14,15]) were used as the starting point to create a more advanced experiment in which some of the facilities introduced by the IBM Bluemix PaaS were exploited to train students at the Federico II University of Naples in a pilot course held by professionals from an external a company, but grafted within their standard classes.

The preliminary results collected from more recent experimentations demonstrate that the use of the IBM Bluemix platform, tacked on the previously crafted eco system based on Eclipse and Jazz, can greatly improve the students' performances [16]. In fact, we observed that students gain core competences faster and they do it in a work-like environment. We also noticed that the paramount part of the architecture is the suite of collaboration services, that has made possible the design and development of the resources useful to the whole students' community.

For a better understanding, we report a brief summary of the results achieved. Basically, the model introduced in Fig. 1 was applied to a software engineering course. The students have been the reference for the opinion mining and needs collection phases while the professionals and the university professors involved established goals and metrics together. Two crash courses on the use of the IBM Bluemix platform were introduced within the regular lessons with an attendance of 120 students. Then, the students were arranged in teams, which developed different components of the same projects and delivered training materials such as, e.g., tutorials, for each other's benefit. Finally, students were asked to compile feedback forms and the overall evaluation of their experience was an average of 4.46 out of 5 stars. It was an encouraging result.

Moreover, students were gently forced to use standards commonly adopted in an open innovation network, which requires mature organizations but produces high quality products and we observed that students' training was satisfactory. We think this is due to the fact that this experience fosters learning methods that are student-led, rather than instructor-led, with professors playing the role of the coach in the learning process, as a real mentor should. This learning model implements a student centric paradigm, which constitutes the basis for collaboration between people within a team and among groups. While observing learning in collaborating groups, we noticed that some groups were *crawling*, others groups were *walking*, others *running* and others even *flying*. To identify those groups that fly and to motivate the other groups to reach the same level means finding the elements that help achieve results faster. This also means that such activities can nurture the creation of smarter universities that are interconnected, enriched, and fed by the ground knowledge developed and spread across the social networks, forcing teachers to have the most updated and relevant curricula. Consequently, they will be attractive for the best students who, in turn, will receive the best formation in a virtuous circle generated by the collaboration between universities and companies.

3.2. Big data, cognitive computing systems, and new skills

We move the focus on to the way we can better exploit big data in the smarter university model. In fact, we are in the transit from the era of information technology to the era of knowledge technology and it is proper to investigate who should be responsible of shaping people with suitable skills to cope with this epochal change. There is no doubt that this is the core mission of the university. However, if the current pace persists, we will be in continuous deficit as we currently are. The solution is transforming the present deficit in a surplus and we already argued that the cooperation between academy and industry would help achieving such a goal. In this new era the role of the academy will be different and the future universities will shift from their current position of "knowledge generators" to assume the role of "generators of knowledge generators" with the help of organizations and companies, that learn from each other, and this is accompanied by an enormous amount of data to extract knowledge from. For this goal to be achieved it is compulsory that knowledge is generated and managed in a better way and, consequently, the new professionals should require different skills. The solution relies in the new wave of cognitive computing systems, which are going to change everything [17]. Perhaps, the new professions will become more interesting and will attract more young people towards university studies or in participating in various courses, also delivered in the spirit of ubiquitous e-Learning and lifelong learning [18,19] that will address specifically knowledge and knowledge extraction from big data.

Companies that need to grow continuously and think about replacing many of their employees might be interested in reconverting them instead of firing them in areas that are challenging and driving. The universities should be prepared for this challenge by creating and offering degrees for the formation of, e.g., data scientists.

4. Evolving from the actual scenario

Whenever the adoption of innovative solutions reflects in the need to move away from old habits and adopt new behaviors, we have to modify existing and well-established paradigms and, consequently, we have to match newly introduced solutions against the previous model. As an example, let us think of the revolution occurred in the transition from traditional banking to e-banking. Another significant example is the digitization process that is still running in the government's administration to the aim of providing digital and online services to the citizens such as, e.g., documents, documentary evidences and certificates. In parallel, digitization of books has dramatically changed the publishing industry and the way books are read, sold and stored as well as the rise of Internet has been radically changing other media such as newspapers, radio and television and the relationships with their audience. Accordingly, such a rapid obsolescence process causes new jobs to replace old ones and this, of course, dramatically impacts on higher education, which has to be ready to follow such evolutions, and, at the same time, must be able to look ahead and act as driver of the change.

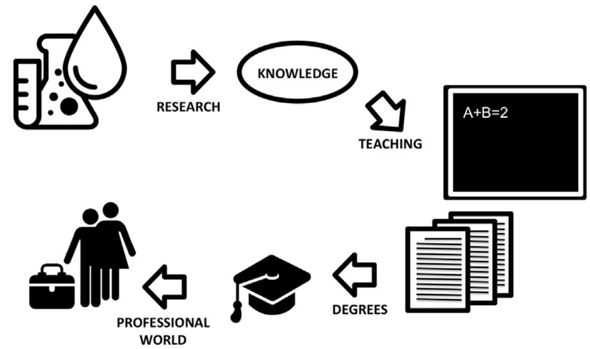

Fig. 2. University as knowledge creator.

4.1. University as knowledge creator

To deal with such fast changing scenarios the role of researchers and teachers has to change and one of the more significant effects will be that they will have to act as knowledge managers, rather than knowledge holders. In fact, according to the current situation, as depicted in Fig. 2, university teachers are the creators of knowledge, owing to their research activity always on-the-edge. From a theoretical point of view, it looks like a perfect model but, in the actual conditions, having specific and deep knowledge in a very narrow research sector does not match with the labor market needs, which are more and more focused on flexibility and interdisciplinary competences. This reflects in the necessity of some kind of orchestration, rather than highly specific skills (indeed this is the case of research and jobs in specific fields like, e.g., medicine).

4.2. Open data, big data, and data scientists

At the same time, we have a large amount of information and data available, coming from many different sources, through many different channels, even if we do not create them, nor we are aware they are being spread. Indeed, we do not need any more to create suited data, as well as we do not need any more to design and maintain gigantic databases. Yet, we still need to manage data and, even more important, to transform them in useful information, which become added value for the production processes. This introduces the role of data scientists as a new cornerstone in the labor market, according to the model depicted in Fig. 3.

In addition, we are observing high growth rates in the quantity of available data while social benefits that can derive from that are getting lower (see Fig. 4). This is mainly due to a missing strategy about the usage and profitable exploitation of such data. This causes the need for new jobs to emerge, such as, for example, data scientists, data analysts, knowledge engineers, knowledge managers, and many more. We argue that, in the present situation, most universities cannot readily cope with this necessity.

It is natural to think that these data can be used to extract knowledge in very specific domains. As an example, see the experiment that the Cleveland Clinic Learner College of medicine of Case Western Reserve University [20] is carrying out in the attempt to create a new machine that augments the human abilities to identify and diagnose diseases in patients. In the experiment Watson has been made capable of consulting a bank of medical data to produce accurate diagnosis of patients. Watson is not

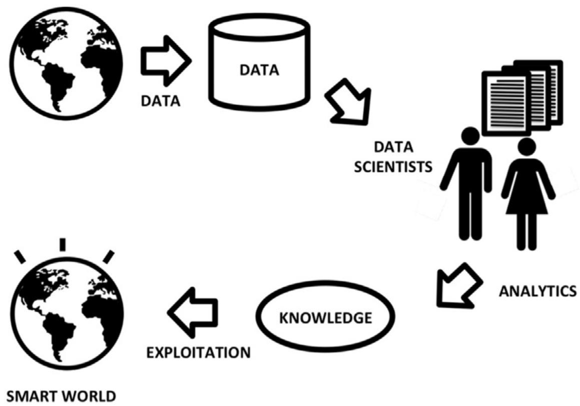

Fig. 3. Data scientists as knowledge creators.

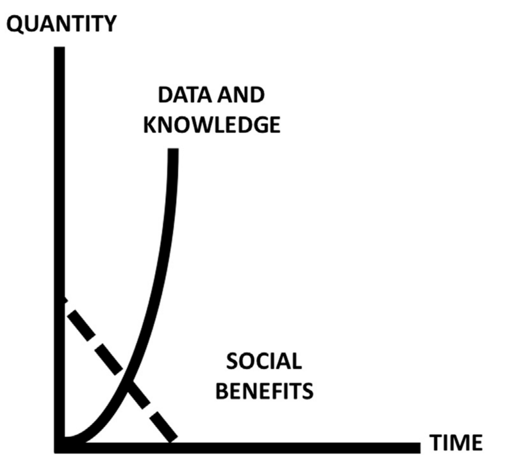

Fig. 4. Qualitative curve representing the relationship between data growth rate and the deriving social benefits.

intended to replace the competencies of the human doctor, neither to substitute the human medical diagnosis and his and her deduction abilities. The aim of Watson is that of helping humans in their findings, providing them with some of its advanced search abilities on big data and with its unique automatic deduction capabilities. This means that in the near future maybe many of us will be paired in our jobs by one or more machines, specifically designed and developed just to support us, augmenting our abilities.

At this point there are two fundamental problems to cope with. The first one is that the data are growing too fast and that the social usability of those data decreases with the time. This warns us that we currently do not have a plan for that. Indeed, we need new professional skills that can extract data from very specific domains, complex data. As the chief economist at Google Hal Varian says in an article on the New York Times by S. Lohr: *"I keep saying that the sexy job in the next 10 years will be statisticians. And I'm not kidding."* [21]. Then, the second problem is that we do not yet know the optimal model for the formation of data scientists, knowledge engineers, knowledge managers, and so on. An estimate says that in the next year in the US alone will need a million data scientists and we only know that the universities are not prepared for this challenge [22].

Finally, when the transition from one era to the other will be over, there will be a new educational paradigm in which the model will be totally centered on big and open data. Open data are a reality to keep under study from the point of view of the educational system. The recent experience of sites like, e.g., Challenge.gov [23]-a site that creates a partnership between the public and

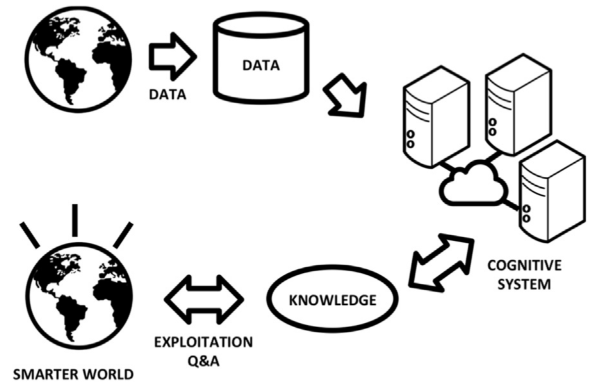

Fig. 5. Cognitive systems act as knowledge creators.

the government to solve important challenges - and Facebook Top Open Data Problems [24], seems suggesting that solutions should come from the cooperation and the participation of everyone to the challenges of this century. In fact, we can observe solutions coming from people working in different area of the problem in consideration only because techniques applied to a domain area were applicable in similar fashion to solve different problems in other disciplines.

4.3. The advent of cognitive systems

In addition, if we all agree that big open data will be the bulk of the forthcoming social and technological development scenario, it is worth noticing that this introduces the need of a new generation of machines able to extract knowledge in an automatic manner, to derive new data from the analysis of existing ones, and to shape new information for specific and unforeseeable application scenarios, based on their previous and ever growing knowledge base (see Fig. 5).

Such machines have to be based on cognitive computing principles and, of course, on suited architectural solutions, exploiting powerful distributed systems in a cloud-computing environment. These cognitive systems will also be able to build useful knowledge for the jobs of tomorrow.

In short, users will be directly interacting with cognitive systems on a daily base. Therefore, they must have a proper formation to "speak" with such systems and they must be able to understand systems that are way more complex than the existing ones. When this point will be reached, the knowledge generation will be more fast and efficient. The knowledge transfer in the social world will be the fundamental key for successful business as we can start observing already now. In Beside statistician, as Varian predicts, the new jobs will look like, e.g., cognitive system developers or cognitive systems integrators, evaluators, and trainers. All of these fascinating jobs will require highly skilled people.

Moreover, it is worthwhile noticing that this revolution will have a dramatic impact on the persons, which are on the users' side. In fact, people will have to modify their attitude towards computers and also will have to develop a different approach in dialoguing with such novel *computer mates*.

5. The skills produced by the smarter university

At present, it is not common to find university courses that provide people with the variety of skills we are discussing around. In fact, people like these should have acquired degrees from both technical faculties, such as, e.g., engineering, and social sciences ones, such as, e.g., psychology and sociology, which can give a technician the additional competences in teaching, social behavior and interaction, communication, problem posing and solving, team work, creativity, and resilience. New technicians and scientists must be molded, to cope with a new generation of services and solutions.

To summarize, we can suggest that we can become the leading actors in the transition from the era of information technology towards the new, even more fascinating, era of the knowledge technology where the enormous amount of data available will be useful to create wisdom. In this scenario, universities must react and be ready to teach novel methodologies and new reasoning paradigms, while industry and organizations could find new market shares to conquer. Specifically, as a consequence of the above considerations, educational models will have to change, to be able to face the new situation, and take into account the needed features. The changes that we are expecting will move education in the direction of being:

(1) multi-disciplinary, including an integrated skill set spanning disciplines like *mathematics*, *machine learning*, *artificial intelligence*, *statistics*, *databases*, *optimization, information systems*, along with a deep understanding of the craft of problem formulation to engineer effective solutions;
(2) multi-domain, to be aware of the socio-economical context in areas such as *medicine*, *energy*, *environment*, *finance*, *transportation*, etc.;
(3) multi-empathic, in fact, professionals as well as machines will interact with: humans such as, e.g., data/knowledge generators or consumers; with cognitive systems, which will be *taught* and not programmed; with a variety of new devices such as machine-augmented humans (assisted by devices and gadgets) as well as, robotic systems, or a mix of all the above;
(4) multi channel, with reference to social interaction and communication between people, between things, and between people and things. The social media will change; messaging cognitive interfaces will change. Consequently people must acquire skills to dialog with interfaces rather than programming them. This will produce the development of a new generation of apps named *cognos*.

Skilled personnel that are a hybrid of data hacker, analyst, communicator, and trusted adviser seem to be a realistic need. More enduring will be the need for data scientists to communicate in languages that all their stakeholders understand. For example, people demonstrating to have special skills in storytelling with data, whether verbally or visually, will be a valuable asset for every organization, also including universities [25].

But the challenge is not only in the identification of the type of skills we need to provide, it is also essential to identify and find both the proper ways to produce them, and the stakeholders involved in the process. We believe that the people involved in the production of such skills will come from different domains such as, for example, from the social sciences, cognitive psychology, developmental methodologies, education, social behavior, etc. In contrast, many other professional skills will be reshaped or updated, e.g., communication, teamwork, problem solving, creativity and resilience skills, etc.

6. Conclusions and future work

There is no doubt that the university must be in charge to produce newly skilled figures in the era of knowledge technology in which we are transitioning. At the current pace we are already in a long-standing deficit. To turn the deficit into surplus we need to set in place a model that supports the educational institution in this new challenge. The smarter university model is the base and some experimental activities performed around the model discussed in this paper seem to confirm that we are proceeding along the right trajectory. The initial results show that collaboration is the base for such transition and that a more tight cooperation between academia and industry will help achieve such a goal. While still central, the role of the academy will be different from the past, and will be transformed from the role of “knowledge generator” to the role of “generator of knowledge generators”. Industries, companies and organizations will have great interest in being involved in this educational revolution since they would be primarily affected by the lack of human resources if the academia fails in its achievement. They also should identify adequate means to improve the competences of their existing personnel so to reallocate many of their employees. In conclusion, in this transformation process, cooperation between universities and the labor market is the key.

To conclude, based on the still running experience reported in this paper, we highlight that the use of a suited cloud computing infrastructure has concurred to solve a lot of problems for the computer laboratories of our universities, reflecting in a reduction of costs in terms of machineries and their maintenance. Future work will be dedicated to the conclusion of open projects and to the study of future applications within the IBM Bluemix ecosystem and Watson.

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