Computers and Artificial Intelligence as Tools for Education in the Forthcoming Era of the Internet of Things and Energy

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Abstract: - The purpose of the present article is to express some thoughts about the new big challenge that Education faces in our days to prepare students for a new way of life with rather uncertain futures in the forthcoming era of a new, but not explicitly known yet, industrial revolution. Our attention is mainly focused on the role that computers and Artificial Intelligence could play in future education and the risks hiding behind this perspective. It is concluded that computers should not be viewed as tools that can perform miracles by solving any kind of problems, but rather as machines performing operations in high speed and therefore enabling users to dedicate their time to quality reasoning and ideas. Computational Thinking appears today as a new way of thinking, which together with critical thinking is necessary for the solution of the complex technological problems created by the rapid development of technology during the last decades. It involves a variety of skills and as a composition of topics from mathematics, engineering, technology and science forms a new mode of reasoning having the potential to create beneficial changes to our society. The impressive applications of Artificial Intelligence in the field of Education (machine learning, social robots, Case-Based Reasoning Systems with computers, etc.) has made a number of specialists on the subject to reach to the conclusion that teachers will not be necessary in future, since the "clever" machines will be able to do everything for educating people. However, it seems that this is actually an illusion, because all these devices have been created and programmed by humans and, although many of them (e.g. the computers) dramatically exceed in speed, it is logical to accept that they will never reach the level of human mind.

Key-Words: - Industrial Revolutions (IR's), Internet of Things and Energy (IoT & E), Cyber-Physical System (CPS), Flipped Learning (FL), Critical Thinking (CrT), Computational Thinking (CT), Artificial Intelligence (AI), Machine Learning, Social Robots, Case-Based Reasoning (CBR).

1 Introduction

The rapid industrial and technological development of the last 150 years caused radical changes to our lives and behaviours transforming the traditional and mainly agrarian human society of the last centuries to our modern society of knowledge and globalization (e.g. see [1, 2], erc). Machines especially designed for massive industrial production, computers, robots and various other "clever" mechanisms and methods of the Artificial Intelligence have already replaced humans in an increasing number of routine jobs, while many new and yet unimagined jobs may be created in future by the continuous development of the new technologies. As a result, the formal Education in all levels is faced with a new big challenge of preparing students for a new way of life with rather uncertain futures in the forthcoming era of a new, but not explicitly known yet, industrial revolution.

The purpose of the present work is to express some thoughts about that challenge. However, in no case this article could be considered as an attempt of a complete analysis of the above subject, because such an effort requires hundreds of pages - as most of the subjects related to Education do - to be integrated. Our attention here is turned mainly to the role that computers and Artificial Intelligence could play in future education and the risks hiding behind this perspective. The paper is organized as follows: In Section 2 a connection is attempted of the past industrial revolutions with the forthcoming new one, which could be characterized as the era of the Internet of Things and Energy and of the Cyber-Physical Systems. In Sections 3 and 4 the role of

computers and of computational thinking respectively in the modern education is studied, while in Section 5 the recent advances and the perspectives of introducing methods and mechanisms of Artificial Intelligence in Education are discussed. The article closes with our final conclusions presented in Section 6.

2 The Industrial Revolutions and the Forthcoming Era of the Internet of Things and Energy

A revolution is defined in general as a rapid and massive series of changes that lead to a radical transformation of the human society. It could be a social, political, economic, industrial or other kind of revolution, but at any case it involves changes in the core of the society.

The *First Industrial Revolution* (1IR), which started from the textile factories of Britain at the end of the 18th Century and spread throughout the world, involved the gradual replacement of the hand by the machine production where machines were mainly used as power sources. The parallel development of the transportation means led to the establishment of big industries and companies in national and later in international level, for which new scientific methods of function and management were applied [3]

Various names and definitions have been actually proposed for the several industrial revolutions that took place since then. According to the World Economic Forum (WEF), the first industrial revolution, characterized by the mechanization on the basis of the steam and water power, was followed by a second one that started at the middle of the 19th Century. The *Second Industrial Revolution* (2IR) looks at the power of electricity and the mass production of large quantities of standardized goods in assembling lines. However, other social thinkers believe that the 2IR, which was ended by the middle of the 20th Century, must be considered as an inseparable part of the 1IR [4].

The *Third Industrial Revolution* (3IR) – or according to the alternative view the second one [4] – is also known as the *era of automation*. This revolution, which began in the 1940's, was mainly characterized by the development of electronics, the automated production and the gradual replacement of the human hands by computers as means of control [2].

In concluding, the combined effects of the previous three (or two) revolutions replaced the power of humans and animals by machines enabling the mass production of goods and led to the digital era of nowadays. However, there were non profitable consequences as well, like the negative environmental impact of the high industrialization, mainly caused by the unlimited use of coal and petrol and by the nuclear energy accidents. The prices of energy and food are increasing in our days, unemployment is high, the economies of many countries are in danger to collapse, the people of the poor countries are suffering and the recovery is not visible. Facing the prospect of a second collapse of the global economy, humanity is desperately looking for a new economic plan that could lead us into a better future.

The idea of a forthcoming new industrial revolution has appeared at the beginning of the 21st Century [5]. The New York Times bestselling author Jeremy Rifkin, a famous social thinker of our time, introduced the term 3IR for this new revolution. In two books published in 2011 and 2014 respectively [4, 6] he describes how the Internet technology, the renewable energy and the 3D-printing are merging to create this powerful revolution. The new technology machines will be supplied by sensors to transport energy from place to place through the Web. On the other hand, the 3-D printers, using powder, molten plastic or medals, will be able to transfer through the Web and reproduce multiple copies of a good in a marginal cost, like the simple photocopy machines do for level images and texts. Consequently, a new advanced *Internet of Things and Energy* (IoT & E) will be created, providing energy, goods and services almost free of cost, like the existing in our days Internet does for the information.

The term *Fourth Industrial Revolution* (4IR), having almost identical meaning with the Rifkin's 3IR, was first introduced by Professor Klaus Schwab, Founder and Executive Chairman of the WEF, in a 2015 article in "Foreign Affairs" [7] In a recent book [8] Prof. Schwab argues that we are already at the beginning of the 4IR. The 4IR is about the emergence of *Cyber-Physical Systems* (CPS) which will be controlled by computer programs through the Internet. Examples of CPS include autonomous automobile and control systems, distance medicine, robots, etc. The world has now the potential to improve impressively the efficiency of services and organizations and even manage ways that can help regenerate the natural environment from the damages caused by the previous IR's.

However, Schwab in his book [8] also expresses serious concerns about the great potential risks connected to the 4IR. He underlines that major changes are needed to our current political,

business, educational and social structures for absorbing smoothly the resulting shifts of the 4IR on the purpose of getting the maximal profit in an effort of creating a better future for our society. This was the theme of the 2016 WEF annual meeting in Davos, entitled "Mastering the 4IR". It is of worth noticing that the industrial plan of Germany promoted the term *Industry 4.0* for the subset of the 4IR connected to industry only. Also, in the 2019 WEF annual meeting, Japan promoted another round of advancements called *Society 5.0.*

3 The Role of Computers in Modern Education

It is difficult to deny that in our modern society of knowledge and information computers are a valuable tool for teaching and learning. The wealth of information in hands of students, the animation of figures and representations provided by the proper educational software that increases the students' imagination and problem solving skills, the rich variety of data and resources that teachers can use working with their students to keep them engaged in the classroom, etc. are some of the benefits obtained by using the computers in Education,

An innovative teaching methodology has been promoted with the help of computers during the last few years known as *flipped learning* (FL) or *reverse learning* which has its roots to the work of Lage, Piatt and Tregla [9]. At the educational level, FL is considered as a mixed process that involves both online and face-to-face teaching and requires turning around the daily didactic processes to which we are accustomed. In fact, the acquisition of the new knowledge by the student is done outside the classroom through the use of digital platforms and technological tools that the teacher has developed. Sams and Bergmann [10] were able to develop an online audiovisual teaching material so that students could do it regardless of factors such as place and time. On the other hand, what is traditionally undertaken as homework is done in class with the supervision of the teacher in order to favor the adequacy of learning and autonomy of students and increase the time devoted to practice, problem solving and deepening of content [11]. Ideas of *social constructivism* about learning [12, 13] are applied during that process.

Some years ago it was believed that human-to-human contact is needed to teach, but as a result of technology we can now do much of this virtually, using computers, videos, etc. Consequently, *distance learning* will become an inseparable part of our lives in future. The *Communities of Practice* (CoP's) are groups of people, experts or practitioners in a particular field with a concern for something they do, and learn how to do it better as they interact regularly, having therefore the opportunity to develop themselves personally and professionally [14, 15]. The *virtual CoP's* through the web appear today as a very promising tool in Education, especially for the developing countries, where people, due to the low budgets, have not many opportunities to travel abroad for participating in conferences, seminars, etc. Students and teachers from different countries can form such CoP's for promoting the learning of a subject matter and teachers and researchers of education for promoting teaching and the research on teaching [16].

However**,** computers should not be viewed as tools that can perform miracles by solving any kind of problems, but rather as machines performing operations in high speed and therefore enabling users to dedicate their saved time to quality reasoning and ideas [17]. Since a computer is created and programmed by humans, the old credo "garbage in, garbage out" is still valid. Nevertheless, through programming it is possible to input information and get an output almost at the speed of light. On the other hand, the practice of students with all kinds of calculations and the rediscovery of proofs of the known results must be continued for ever; otherwise they will gradually loose the sense of numbers and symbols, the sense of space and time, and they will become unable to create new knowledge and technology [18].

4 Computational Thinking in Problem Solving

Problem-solving (PS) is a very important component of the human cognition that affects our lives for ages [3, 19]. The ability of solving composite non routine problems requires *critical thinking* (CrT), which is a higher mode of thinking, where analysis, synthesis and evaluation are combined giving rise to other skills like inferring, estimating, predicting, generalising and creative thinking.

However, the rapid development of technology during the last decades created new complex technological problems the solution of which requires the combination of CrT with another mode of thinking that has been termed as *computational thinking* (CT). The term CT was first introduced by S. Papert [20], who is widely known as the "father" of the Logo software. However, it was brought to the forefront of the computer society by J. Wing [21],

who describes it as involving solving problems, designing systems and understanding human behaviour by drawing on principles of computer science. CT involves also analysis and organization of data, automation of problem solutions and application of them for solving similar problems. Thus, according to Liu and Wang [22] CT is a hybrid of other modes of thinking, like abstract, logical, algorithmic, constructive thinking and modelling thinking that synthesizes all the previous modes of thinking for the solution of the corresponding problem.

CT does not suggest that problems must be necessarily solved exactly in the way that a computer does. Voskoglou and Buckley [18], considering the problem as an obstacle that has to be overcome, presented a model that elucidates the connection between CrT and CT during the PS process, where the existing knowledge forms the link between them. This hypothetical model, that could be used to conceptualize the PS process of a complex technological problem, is graphically illustrated in Figure 1. In case of simpler problems the 3-D model of Figure 1 could be transformed to a linear form on the level (see Figure 1 in [18]).

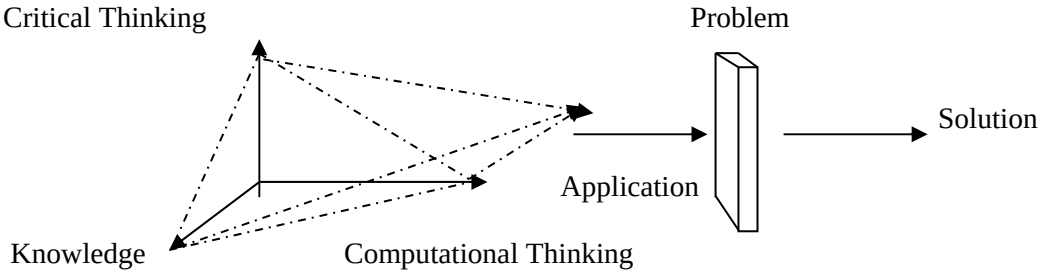

Figure 1: The PS model

Although recent studies address the necessity to become trained in CT before learning *programming* [21] the best way to learn it explicitly is through programming that employs all the components of CT and provides a framework not only for computer science, but for all sciences. In thinking as a computer scientist, students become aware of processes that can be analysed within an algorithmic framework. CT, as a composition of ideas from mathematics, engineering, technology and science forms a new mode of reasoning having the potential to create beneficial changes to our society.

5 Applications of Artificial Intelligence to Education

Roughly speaking, *Artificial Intelligence* (AI) is the area of computer science focusing on the creation of intelligent machines working and reacting like humans.

In this section recent advances and perspectives of introducing methods and mechanisms of AI in Education are discussed [24]. Among them *machine learning*, *Case-Based Reasoning* (CBR) *Systems* in computers and *Social Robots* are some of the most representative examples.

The term machine learning comes from the idea that an algorithm is learning from a training dataset. Machine learning can be distinguished to *supervised learning*, in which both input and desired output data - which can be thought of as the teacher - are labelled for classification to provide a learning basis for future data processing, and to *unsupervised learning* where only the input data are given and the algorithms are able to function freely in order to learn more about the data. As a simple example of the former case consider the sequences of positive integers 1, 2, 3, 4, 5, 6, 7, …. as input and 1, 4, 8, 16, 25, 35, 49, …. as output, which indicates the raising to the second power. Applications of supervised learning are typically broken down into two categories, *classification* where the output value is a linguistic expression (e.g. true or false), and *regression* where the output is a real value (e.g. price or weight). When only some of the input data are labelled with output information, we speak about *semi-supervised learning* [25].

CBR is the process of solving problems based on the solutions of previously solved analogous problems (past cases) [26]. For example, a physician who cures a patient based on the therapy that has previously applied to patients presenting similar symptoms is using the CBR methodology. The use

of computers enables the CBR systems to preserve a continuously increasing "library" of past cases and to retrieve in each case the suitable ones for solving the corresponding new problem.

CBR is a four step process involving the following steps: *Retrieve* (R_1), *Reuse* (R_2), *Revise* (R_3) and *Retain* (R_4) the suitable past case or cases. Through the revision the solution is tested for success. If successful, the revised solution is directly retained in the CBR library, otherwise it is repaired and evaluated again. When the final result is a failure, the system tries to compare it to a previous analogous failure (transfer from R_3 back to R_1) and uses it in order to understand the present failure, which is finally retained in the library. A graphical representation of the CBR process is that shown in Figure 2 [27].

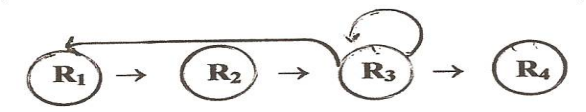

Figure 2: Graphical representation of the CBR process

A social robot is an AI machine that has been designed to interact with humans and other robots. Such kind of robots are used for entire job functions at home by understanding speech and facial expressions, in customer service, in education, etc. Examples of Education applications are the robot *Tico* that has been designed to improve children's motivation in the classroom, the robot *Bandit* that has been developed to teach social behaviour to autistic children, etc [28].

The theory of *fuzzy sets* introduced by Zadeh 1965 [29] and the resulting from it *fuzzy logic*, an infinite-valued logic being a generalization of the traditional bi-valued logic, are strictly connected to AI. Fuzzy logic has been found many and important applications to almost all sectors of the human activity; e.g. see [30, 31] etc. Courses on fuzzy sets and systems are already appearing in the curricula of certain university departments [32] and for sure they are going to be expanded in the near future.

The impressive advances of AI in the field of Education have made a number of specialists to believe that teachers will be replaced by the "clever" machines in future for educating students. "Horses have been replaced by cars" they argue parallelizing the two situations. However, I am among those many people believing that actually this will never happen. In fact, the acquisition of information is valuable for the students, but the most important thing is to learn reasoning logically and creatively. The latter is impossible to be succeeded through the help of computers and of the other "clever" machines of AI only, because all these devices have been created and programmed by humans and, although many of them - e.g. the computers - impressively exceed humans in speed, it is logical to accept that they will never succeed to "think" like the humans do.

6 Conclusion

The discussion performed in the present paper leads to the following conclusions:

- The forthcoming, but not explicitly known yet, new industrial revolution (the fourth according to WEF, or the third according to other social thinkers) could be characterized as the era of IoT & E and of the Cyber-Physical Systems. This new revolution has the potential to change our lives by bringing a better future for the humanity, provided that we will be prepared to adopt gently the dramatic changes that will follow.
- The formal Education is nowadays faced with a new big challenge of preparing students for a new way of life in this new era with rather uncertain futures.
- In this work the important role that computers and AI could play for the Education in future and the risks hiding behind this perspective have been discussed. However, it is rather an illusion to believe that computers and the other "clever" machines of AI will replace the teachers in future, because all these devices have been created and programmed by humans and therefore it is logical to accept that they will never succeed to "think" like the humans do.

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