University 4.0: The Industry 4.0 paradigm applied to Education

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Abstract. The industry has undergone various industrial revolutions leading to major upheavals in all activities of human life, particularly in the field of education. Technology has become ubiquitous in educational organizations seeking to respond effectively to the demand for improvement, optimization, and personalization of large-scale, technology-supported education. Possibilities for automatically tracking the progress of learners become possible, at least for assessing attendance, progress, and acquisition of knowledge or skills. Knowledge sources are increasingly heterogeneous and complex in learning environments. With continuous innovations in the way we teach and learn, there is a need to rethink and transform the model of integrating technology into teaching in order to achieve intelligent collaboration and coordination between technology and people for learning. In this article, we propose an approach to be taken into account in the natural evolution of educational institutions under the term of University 4.0. The University 4.0 concept is inspired by the Industry 4.0 paradigm and applies its concepts to higher education to provide better responses to the specific needs of each learner. This paper presents a state of the art on the Industry and Education revolutions and in particular the digital and pedagogical transformations in education from Education 3.0 to Education 4.0, as well as the challenges of University 4.0.

Keywords: Industry 4.0, Education 4.0, University 4.0, Cyber-Physical Systems, Autonomic Computing, Knowledge Base, Semantic Web

1 Introduction

The industry has undergone various industrial revolutions leading to major upheavals in all activities of human life, particularly in the field of education. Thus, educational organizations can draw inspiration from the new paradigm of the fourth industrial revolution (Industry 4.0), which consists of digitizing organizations and automating business processes in order to better meet the specific needs of each product or service. Indeed, information and communication technologies (ICTs) have become omnipresent in educational organizations seeking to respond effectively to the demand for improvement, optimization, and personalization of large-scale, technology-supported education.

Moreover, we are moving towards ultra-connected universities, characterized by a weak combination of technology and people at the service of learning. In this context of mass education, even without technology, it is already a problem for the teacher to be able to follow each learner. With the plurality of learners with different profiles in universities, it is extremely complex and resource-intensive to provide each learner with the personalized follow-up necessary to improve learning.

Systems for analyzing and adapting learning based on Big Data, Machine Learning, Artificial Intelligence are being developed as new tools for the improvement and personalization of learning. The emergence of the Internet and technological advances have also favored the adoption of several pedagogical approaches (online training, flipped classroom, blended learning, etc.) aimed at improving teaching. These ongoing innovations in the way we teach and learn require us to rethink and transform the model of integrating technologies into teaching in order to achieve intelligent collaboration and coordination of physical and/or virtual actors at the service of education.

In this article, we propose an application of the concepts of Industry 4.0 to higher level educational organizations in order to evolve towards University 4.0 to provide better responses to the adaptation of learning and the differentiation of the pedagogical path of each learner. Our research work is part of the transition towards this new educational revolution in order to ensure an alliance between technology and human beings in the service of improving learning.

This paper presents a state of the art on the Industry and Education revolutions and in particular the digital and pedagogical transformations in education from Education 3.0 to Education 4.0, as well as the challenges of University 4.0, and the proposed solution.

2 State of the Art

In this section, we present the paradigms of the fourth industrial revolution and the fourth educational revolution, an analysis of the current digital and pedagogical transformations opening the way to a new educational revolution.

2.1 The paradigm of the fourth industrial revolution (Industry 4.0)

To better understand the fourth industrial revolution, it is necessary to review the previous industrial revolutions [1]. The first industrial revolution (Industry 1.0) was characterized by the mechanization of the industry with limited production based on the use of oil and steam engines as a source of energy. The second industrial revolution (Industry 2.0) was based on the organization of work and the use of electricity to promote mass production. The third industrial revolution (Industry 3.0) was based on the integration of electronic components and information technology in the industry for the automation of production tasks. Nowadays, as a direct consequence of Industry 3.0, we are witnessing the development of intelligent industrial systems thanks to the permanent integration of advanced technologies (Artificial Intelligence, Cloud

Computing, IoT, Big Data, robotics) favoring the advent of the fourth industrial revolution (Industry 4.0).
Industry 4.0 is marked by a technological fusion of the boundaries between the physical, biological, and digital worlds in order to design intelligent cyber-physical systems [1, 2]. Thus, there is a need to integrate the physical and digital worlds in order to improve the management of products, business processes, and services in Industry 4.0 [3]. Industry 4.0 also encourages a shift from mass production or service provision to customized products and services based on individual customer requirements [4]. The authors [1] [2] [3] indicate that the Industry 4.0 paradigm is mainly based on the integration of advanced technologies such as Artificial Intelligence, robotics, big data, cloud computing, the Internet of Things, the Internet of Services, and 3D printing in the industry to automate and digitalize manufacturing processes.

The various industrial revolutions have always led to major upheavals in all activities of human life, especially in the field of education. With Industry 4.0, it has become imperative for educational organizations to move towards a new revolution: Education 4.0.

2.2 The paradigm of the fourth educational revolution (Education 4.0)

In order to understand Education 4.0, it is important to show the evolution of education since its origins, which we could consider as Education 1.0. Ernst & Young LLP [5] provides a review of previous educational revolutions from antiquity to the present day. The first educational revolution (Education 1.0) was characterized by a mode of teaching that was informal, church-controlled, and accessible to a privileged few in religious institutions. The second educational revolution (Education 2.0) emerged in response to society's need to democratize education and to train as many people as possible, giving rise to mass education with advanced and formal teaching methods focused on educational institutions (schools, colleges, universities). In the third educational revolution (Education 3.0), information, and communication technologies (ICTE) are now being increasingly integrated into education. New models of open and online education (Massive Online Open Courses or MOOC, Corporate Online Open Course or COOC and Small Private Online Courses or SPOC), has completely overturned the way we learn and teach by making education accessible to the general public without constraints of space, time and place and by providing the premises for the next educational revolution. According to [6], "Education 4.0 will somehow complement the phenomenon of digital inclusion in our daily lives where human beings and machines are lined up to extract the solvent, and of course, discover new theories on innovation". The Education 4.0 paradigm could be defined on the basis of two emerging trends, one based on general innovations and changes in education and pedagogy, and the other on the integration of technologies introduced by Industry 4.0 into education.

On the one hand, Education 4.0 is a vision of the future of education that exploits the potential of digital technologies, personalized data, and the opportunities offered by this connected world to foster lifelong learning [7]. It is an educational revolution that allows learners to be the architects of their learning, characterized by the personalization of learning with flexible, dynamic, and adaptive learning pathways [5].

With this first trend, Education 4.0 launches educational organizations into a dynamic of adopting new technological and pedagogical transformations to better respond to the specific needs of each learner.

On the other hand, Education 4.0 is a direct consequence of the emergence of the 4.0 industry. In order to prepare future generations of learners for the fourth industrial revolution, it is necessary to align education with Industry 4.0 [8]. Education 4.0 is about integrating the technological advances of Industry 4.0 such as 3D printing, augmented reality, virtual reality, cloud computing, hologram, biometrics, multi-touch LCD, Internet of Things, artificial intelligence, big data, QR-code for educational purposes [6]. With this new trend, Education 4.0 encourages the transformation of the process of integrating technological advances into teaching and learning in order to promote alignment between education and industry 4.0.

By combining these two trends, the Education 4.0 paradigm constitutes a set of technological innovations and pedagogical transformations in education that promote a combination of man and technology in the service of improving and adapting learning to better meet the expectations of Industry 4.0.

2.3 Analysis of digital and pedagogical transformations in education

Digital transformations

Today, digitalization is changing everything, and we are witnessing major revolutions in education that are disrupting the interaction between the different actors in education. The current context of digital transformations is based on the permanent integration of technology as a learning tool that promotes the development of new innovative learning methods and intelligent environments:

Learning Management Systems (LMS)

Learning management system solutions provide automated administration services for learning-related activities (management of resources, training paths, learners, trainers, etc.). LMS also offers learners the possibility of learning at their own pace, of consulting learning resources at a distance, and of individualized learning. There are proprietary LMS platforms such as 360Learning, CrossKnowledge, and Dockeos, and open-source platforms such as Canvas, Claroline, Moodle, and Open edX. Moodle is the most widely used LMS solution in the world with its open code which allows great flexibility in the evolution of training digitization needs [9].

Mobile learning

The increasing use of computers, tablets, and smartphones in classrooms has become an emerging trend in education. According to a survey by Pearson Education [10], nine out of ten (87%) students in US universities use a laptop, electronic notebook, or Chromebook computer every week to do their homework.

Interactive and fun contents

The interactive and playful content immerses the learner in a sensory experience (touch, sight, hearing) with additional information enriching the learner's experience. There are several applications in higher education, e.g. in an astronomy course, teachers can use 3D representations of the earth and the sun so that learners better understand the relationship between the earth and the sun [11].

Virtual teaching assistants (Chatbots)

The use of chatbots has become ubiquitous in education [12, 13]. These conversational tools (text or audio) based on computer programs offer learners the possibility to study, search for information, or benefit from pedagogical assistance via a virtual agent. For example, at the Georgia Institute of Technology in the United States, a virtual teaching assistant called Jill Watson has been deployed to improve exchanges in MOOCs. Jill Watson independently answered routine questions and frequently asked questions from students while posting weekly announcements [14].

Digital interactions (clickers)

To encourage participation, commitment, and motivation of the learner, class response systems (clickers) have been developed. According to [15], clickers are small, sophisticated technological devices that allow the learner to quickly answer questions in the classroom. Clickers also provide digital interactions between the teacher and learners to promote learner satisfaction, attention, and enjoyment of learning.

Intelligent Tutoring Systems (ITS)

Intelligent tutoring systems have been developed in order to adapt learning resources to the specific needs of each learner in the context of online learning. According to [16], with ITSs the learner can receive content that was not available in the repository when the content designer developed a given pedagogical strategy. Depending on the state of the knowledge base at a given time, e-learning elements can be provided to meet the learner's needs.

Technological innovations have fostered pedagogical transformations that are changing the way we teach and learn. In this context of large-scale, technology-supported education with different learner profiles, it has become essential for universities to adopt new pedagogical approaches to provide responses tailored to the specific needs of each learner.

Pedagogical Transformations

The current context of universities is marked by the adoption of new pedagogical approaches to facilitate access to educational content and improve the quality of learning. These approaches include

Active pedagogy

Active pedagogy is a broad concept, most often referring to student-centered and activating teaching methods and teacher-led activities [17].

It is a pedagogical approach that aims to make the learner an actor in his or her learning process with active participation in the construction of knowledge.

Project-based learning

Project-based learning is a practice of active pedagogy that allows managing learning through the realization of an individual or collective project. This pedagogy allows learners to become familiar with the complexity of the professional world while helping them to build their personal and professional projects. There are several applications [18] [19] based on this pedagogical approach which places the learner in a complex problem-solving situation.

Flipped-classroom

Flipped-classroom is an approach that consists of reversing the nature of activities in the classroom (lectures) and at home (homework assignments). Reverse class means giving the students autonomous activities of the low cognitive level to be done at home, in order to favor collaborative work and learning tasks of high cognitive level in the

classroom, by putting the students in activity and collaboration [20].
There are several applications [21] [22] [23] of this pedagogical approach aimed at giving the learning environment a mix of the use of technology with practical educational activities.

Game-based pedagogy

Definitions of game-based learning through play emphasize above all that it is a type of game with defined learning outcomes [24]. Educational games are seen as beneficial tools for learning and developing skills in a number of areas, particularly in improving education [25].

Blended learning

Blended learning is a hybrid concept that combines face-to-face and online teaching. According to [26], *blended learning integrates the use of learning theories and teaching practices in a flexible, multimodal, and multi-linear redesign, with multi-linear learning referring to individualized and self-paced learning processes*.

Technological innovations and pedagogical transformations have fostered enormous needs in teaching and learning. To improve and adapt learning to align with the needs of learners and industry, educational organizations are moving towards the concept of Education 4.0.

3 Challenges in Education 4.0

Nowadays, proposals for applications or examples of implementation of the Education 4.0 paradigm are increasingly being developed in educational organizations.

Fisk [7] proposes general innovations and changes needed to implement the education 4.0 paradigm. This proposal is based on the adoption of nine trends in the world of learning which are : (i) learning in different times and places, (ii) personalization of learning, (iii) adaptive and dynamic learning processes, (iv) project-based learning, (v) field experience, (vi) data interpretation, (vii) formative assessment, (viii) student ownership, and (ix) the mentoring system. In this approach, the Nine Trends in Education 4.0 contribute significantly to the transformation of the current role of the teacher by putting the learner at the center of the learning process.

Hussin [29] implements the nine trends in education 4.0 proposed by Fisk [7] in the context of a language course based on the use of several digital tools with a varied content format (text, video, file, website links). The author uses educational technologies (*OpenLearning*, *Mentimeter*, Padlet, Kahoot) to implement reverse pedagogy, activity-based learning, diagnostic and formative assessments, active pedagogy, and badges to reward learner participation and creativity. According to the author, despite the instability of the internet connection encountered by the students, the approach was well appreciated by the students who would like other courses to follow this approach.

Intelitek [8] develops an implementation of Education 4.0, based on the transformation of four paradigms of current education which are : (i) the paradigm of the empty brain to be filled, (ii) the requirement of basic knowledge, (iii) the interference of the computer with thinking and learning in individual mode. Learning environments are inspired by Industry 4.0 and the development of transportation systems, health systems, and much more. The Intelitek Education 4.0 learning system is based on fundamental principles of Education 4.0 such as the personalization of learning paths, formative assessment, mentoring, and the divergence and plurality of learner profiles.

Mourtzis et al [30] present "The Teaching Factory Concept" which is an application of the Education 4.0 paradigm in the teaching of manufacturing skills. This approach developed is based on the integration of cyber-physical systems and industry 4.0 technologies in teaching. This concept is applied to a case of using courses on the manufacture of a remote-controlled car based on a combination of traditional manufacturing techniques with technologies introduced by Industry 4.0. This application introduces students to advanced manufacturing techniques, integration, and analysis of data collected from design to prototype manufacturing in order to better perform performance tests during the process.

In the literature, there are proposals and cases of application of the Education 4.0 paradigm, which in most cases focus on aligning education (Education 4.0) with the next industrial revolution (Industry 4.0). According to Jhingan [5], *universities need to move away from process-oriented, technology-supported mass education systems to a new teaching method that values individualized learning. Flexible learning paths, emphasis on the transmission of life skills, student-centered learning methods, and the use of technology introduces the concept of Education 4.0*".

Current research to develop tools to improve, adapt, and personalize learning is part of the solution to the problems encountered in educational organizations.

Analysis of the barriers and obstacles to education 4.0

Today, Education 4.0 promotes the ubiquitous availability of information and increasingly dynamic teaching and learning processes [6]. The sources of knowledge coming from the teacher, from physical books, enriched by a large amount of multimedia resources on the Internet (Wikipedia, YouTube, learned societies, electronic articles, and books...) are increasingly heterogeneous and complex, thus limiting the capacities of analysis and use of learning data of systems based on learning improvement. Technology has become ubiquitous in educational organizations seeking to respond effectively to the demand for improvement, optimization, and customization of learning open to the general public. With this accelerated integration of technology in education, we are moving towards ultra-connected universities integrating connected people, robots, objects, and services in the service of learning. This cohabitation between technology and humans is characterized by their weak alliance in the service of adapting learning and differentiating the educational path of each learner.

In order to improve the quality of learning in universities, the challenges of learning can be summarized around three major axes:

Reactivity: the ability to provide teaching adapted to the specific needs of each learner with progressive assessment and recommendations (feedback to the learner or teacher) during the learning process and not only at the end of the process (summative assessment).

Flexibility: flexibility in pedagogical organization, the use of teaching tools, means of communication with the learning environment, as well as at the level of learning pathways in order to better respond to individualized mass education.

Efficiency: optimizing the use of resources (human, financial, technical), i.e. having more successful learners while reducing the cost of their teaching.

Despite the Education 4.0 paradigm, universities are characterized by a plurality of learners with different profiles, interests, and learning rhythms, which makes it extremely difficult to implement certain resource-intensive techniques to provide each learner with personalized follow-up. The need to integrate resources and actors to allow the design of intelligent and self-adaptive cyber-physical systems capable of managing learning processes also slows down the perfect application of the education 4.0 paradigm. Difficulties in adapting to the individual and evolving needs of learners and teachers in the construction of reusable and self-adapting learning objects, guided by training models sharing common semantics on knowledge repositories, skills for better assessment and remediation of learning outcomes are obstacles in the transition to Education 4.0.

As noted, [1], "*The rapid pace of emergence of the 4.0 industry requires that Education 4.0 also jumps from the current Education 2.0 to Education 3.0 / 4.0 framework*. Thus, in this Education 4.0 context, universities need to adopt education automation to produce innovation in educational organizations [1].

4 Definition of the University 4.0 Model

In addition to considering the requirements of Education 4.0, the University 4.0 provides autonomous management of learning processes based on the integration of the physical and digital worlds in order to improve and adapt learning.

We take inspiration from the different industrial and educational revolutions to draw an analogy of the common features between the different industrial and academic revolutions, illustrated in Figure 1. We have the first university revolution (University 1.0) which is characterized by a mode of learning limited to a privileged few. The second university revolution (University 2.0) is characterized by a massification of education with the democratization of access to knowledge. The third university revolution (University 3.0) represents the era of integration of digital devices as teaching and learning tools. The concept of the fourth university revolution (University 4.0) that we propose aims at applying the Industry 4.0 paradigm in universities to foster the automation, adaptation, and personalization of learning processes.

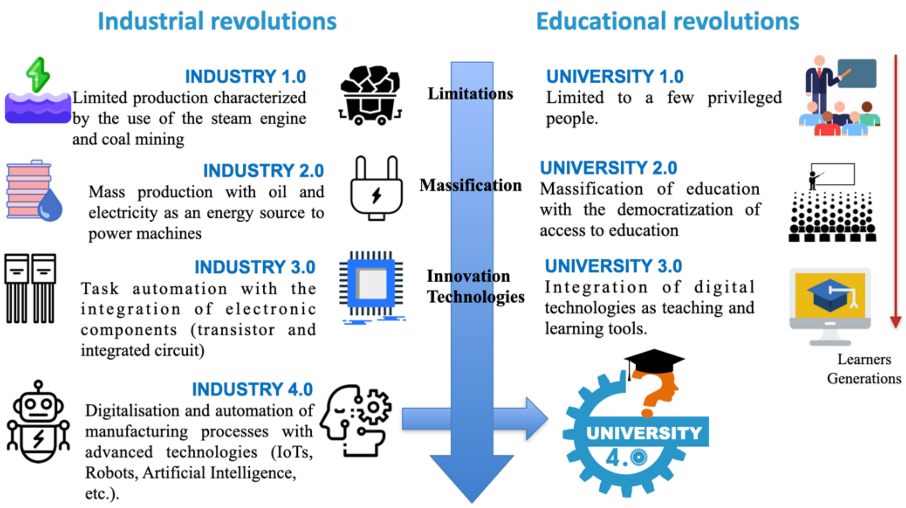

Fig. 1. Analogy between the different industrial and university revolutions

In this article, we propose to move higher education institutions towards a new educational revolution, entitled "University 4.0". In this University 4.0 concept, we draw on the paradigm of Industry 4.0 by applying its concepts to the university to provide better responses to the specific needs of each learner. Our contribution to this issue aims to foster intelligent collaboration and coordination between physical and virtual actors in order to adapt and personalize learning. With our concept, we aim to enable universities to provide adaptive teaching that meets the needs of its learners.
Faced with a dynamic learning environment, characterized by a permanent integration of new learning tools, we propose to rethink and transform the model of integration of technology in teaching for a better alliance of technology and human beings at the service of learning.

4.1 Actors

In order to better ensure this transition towards University 4.0, we will propose a common space for the multiple actors of University 4.0 (people, data, objects, and connected services, etc.) providing a better representation of events, symptoms, diagnoses, and plans of recommendations or actions for the definition and execution of personalized learning processes. Furthermore, by representing and managing this knowledge, this system allows the automation (or semi-automation) and optimization of learning processes, as well as the capacity to adapt to dynamic and unpredictable changes in their environment. This will enable educational organizations to better adopting the integration of technologies and the autonomous management of learning processes in University 4.0.

4.2 Semantic space

In order to automate learning processes, it is necessary to have a format for describing all entities (resources, actors, properties, relationships, events, etc.) that allow for reasoning on this description. With the complexity of the actors in the learning environment, a language that can be understood and interpreted by both humans and machines is indispensable for intelligent collaboration and coordination between the different actors. It is for these reasons that we have adopted a knowledge base with an ontology-oriented approach. This will allow us to have a shared conceptualization leading to a formal and explicit specification language that is understandable by both humans and machines for better collaboration between people, between machines, and between people and machines.

4.3 Autonomous learning

The autonomous management of learning processes requires a system capable of implementing functions of description (complete description of actors, events, changes), diagnosis (identifying dysfunctions, problems in learning processes), prediction (capable of making a prediction about what will happen in the future, for example predicting the failure of a student) and prescription (proposing recommendations to the student or teacher in order to improve the quality of learning). This is why we have adopted the IBM MAPE-K reference architecture of Autonomic Computing [27, 28] to provide our system with autonomous management modules: *Monitoring*, *Analysis*, *Planning*, *Execution*.

4.4 Autonomous architecture

The architecture of the solution we propose is based on a data source from the learning environment that can be composed of an LMS, learning objects, virtual learning environments, as well as the interaction traces of the actors. After the collection and storage of the learning data using an Learning Record Store (LRS), these data are intended for the customization system constituted by the autonomous learning management based on the IBM *MAPE-K* reference architecture of Autonomic Computing with the autonomous manager modules around an ontological knowledge base :

Monitoring dedicated to the monitoring of the system, its properties, and its environment through the collection of all kinds of information from the LRS in order to determine the symptoms, i.e. to give meaning to the data, so that it becomes relevant information for our educational decision-making process.

Analysis processes the information contained in the symptoms received according to the policies and strategies defined in the KB.

Planning develops action plans describing how the required changes will be implemented.
Execution implements the planned plans by carrying out the actions in the form of recommendations to the teacher (relevance of an objective).

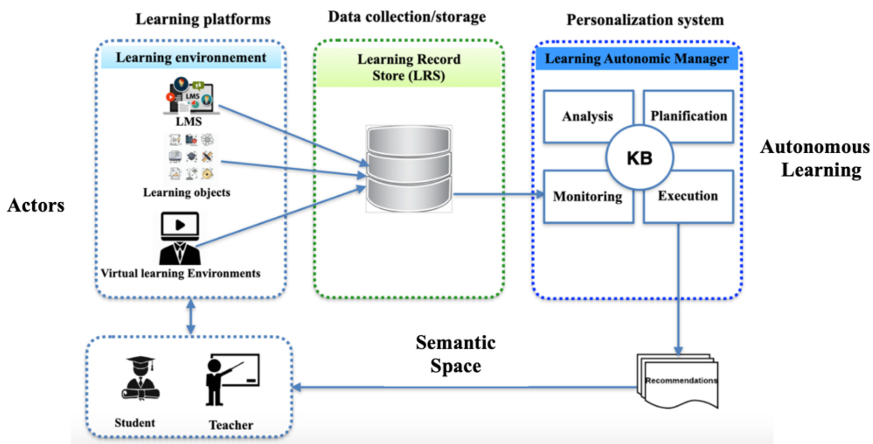

Fig. 2. Autonomous Learning Architecture

5 Evaluation and validation of our proposal

To evaluate and validate our system, we intend to use the Technology Acceptance Model (TAM) which was developed by Davis in 1989. This model will allow us to determine the behaviour of students and teachers in using our solution. The TAM is based on two main and external variables (Perceived Usefulness and Perceived Ease of Use) that affect the level of acceptance and motivation of students and teachers to use our system.

- **Perceived Usefulness (PU)**
  The PU variable is seen as the measure to which students and teachers believe that the autonomous learning management system is useful for improving performance and achieving the desired satisfaction.
- **Perceived Ease of Use (PEU)**
  The variable PEU is defined as the measure to which students and teachers feel that the use of the system is free of physical and mental strain. That is, the fact that the system provides autonomous management of personalized and

adaptive learning processes by implementing description, diagnosis, prediction, and prescription functions.

6 Conclusions and Future works

This article proposes a new concept of University 4.0 to contribute to the transition to Education 4.0. University 4.0 is essentially based on the application of Industry 4.0 concepts in educational organizations. In this concept, we want to adopt automation (or semi-automation) and optimization of learning processes based on the principle of automation and digitalization of manufacturing processes in Industry 4.0. University 4.0 will enable educational organizations to better adopt the integration of technologies and the autonomous management of learning processes in University 4.0 for better management of the adaptation and differentiation of learning paths, as well as the optimization of learning processes. This autonomic management of learning processes is essentially based on the semantic web technologies with an ontological knowledge base and on IBM's reference architecture of Autonomic Computing.

This system will help to facilitate intelligent collaboration and coordination between the multiple actors of the University 4.0 (people, data, objects and connected services, etc.) for the improvement of learning.

In a forthcoming paper, we will publish the results of the solution we are deploying at the level of a distance master's degree with 30 students spread around the world with a total hourly volume of 300 hours of classes.

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