DOI: https://doi.org/10.1109/EDUCON.2019.8725188

What Can You Do with Educational Technology that is Getting More Human?

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Abstract—**Technology is advancing at an ever-increasing speed. The backend capabilities and the frontend means of interaction are revolutionizing all kinds of applications. In this paper, we analyze how the technological breakthroughs seem to make educational interactions look smarter and more human.**

After defining Education 4.0 following the Industry 4.0 idea, we identify the key breakthroughs of the last decade in educational technology, basically revolving around the concept cloud computing, and imagine a new wave of educational technologies supported by machine learning that allows defining educational scenarios where computers interact and react more and more like humans.

Keywords— ***mixed realities, multimodal interaction, voice assistants, mixed social networks, cloud computing, machine learning, education 4.0***

I. INTRODUCTION

The concept Industry 4.0 [1] (see Figure 1) was coined to reflect the major breakthroughs in industry, from the mechanization thanks to steam power (first revolution) to the assembly line and the availability of electricity (second revolution) to the automation of factories (third revolution), and finally to the availability and processing of big data thanks to Internet services and artificial intelligence [2].

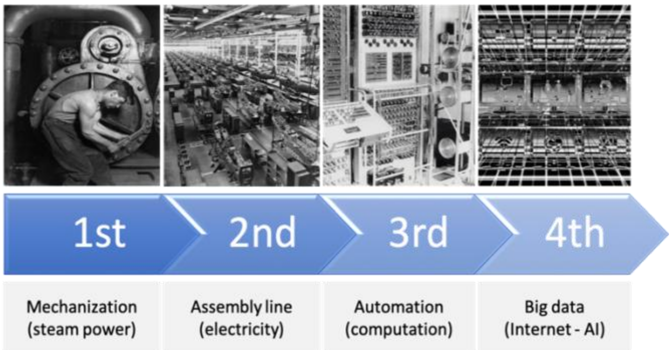

Figure 1: From Industry 1.0 to Industry 4.0

In a similar way, we can identity four major revolutions in education, although they don't correspond exactly to the same time periods and technologies as in the case of industry (see Figure 2).

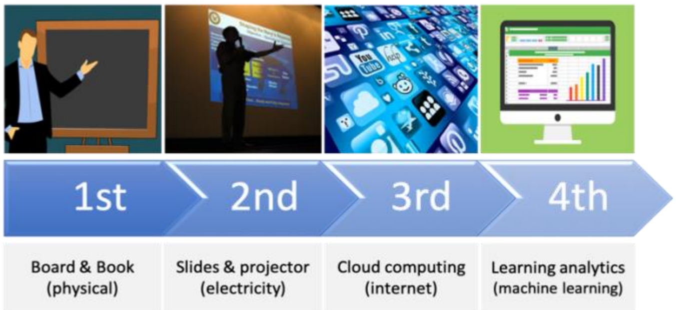

Figure 2: From Education 1.0 to Education 4.0

The first one corresponds to the invention of the printing press. This brought a higher efficiency in book production and therefore a faster and wider dissemination of knowledge. Into Education 1.0 we will include also the blackboard, although it is only a bit more than 200 years old. In this way, we cover all physical, mechanical technologies that can be used both for the dissemination of knowledge in books and for the explanation in class. Interaction, so essential for learning, takes place physically, in a controlled physical environment in which students can experiment with real objects they have at hand (e.g., chemical elements to understand reaction processes in Chemistry, corpses to perform a dissection in Medicine, etc.). Collaboration between students takes place at this level in a face-to-face environment, and in a synchronous way.

For Education 2.0, electricity is necessary. Education 1.0 can be carried out without electricity, Education 2.0, not. A computer and a projector could be used, but no internet is required. This level corresponds to typically using slides and a slide projector or even a computer with PowerPoint or similar tools and a computer projector in class. This is today a widely-used setting [3]. In this case, interaction no longer requires a dedicated physical space. Simulators can be used to carry out experiments where the real elements are unavailable, simulating the behavior of the environment under study (e.g., the result of two molecules when colliding in Chemistry, the behavior of the circulatory system in Medicine, etc.). Collaboration between students still happens in a face-to-face environment, and needs to be synchronous, although it can be mediated by technology, leading to the emergence of the field of research called Computer Supported Collaborative Learning (CSCL).

Education 3.0 is enabled by internet and cloud computing [4]. MOOC platforms are a good representative of this revolution [5]. Content is in the cloud and discussion forums as well. Both teacher explanations, typically through videos, and interactions among actors (teachers and students) go through the cloud. LMSs (Learning Management Systems), as earlier, possibly less developed ancestors of MOOC platforms, also fall into this category. They were used basically for out-of-class usage [6]. The use of mobile apps for engagement in class such as Kahoot! or Socrative, is also a good use case [7]. They promote active pedagogies in class. Note the difference to the use of PowerPoint, where information flow goes one way from the teacher to the student and feedback has to go through the physical channel, which greatly limits the interaction of students. However, with mobile engagement apps interaction goes through the cloud at a much higher bandwidth: all students can give feedback. Therefore, the individual student can (must) interact more with the teacher [8]. In this case, more powerful simulations become available for students, as processing capabilities rely on the cloud. Moreover, students can make use of remote laboratories in which to experiment (remotely) with real elements, but at a much lower cost. Collaboration now can happen virtually, and be synchronous (e.g., through a videoconference tool, or a shared online document) or asynchronous (for example, through the forum in an LMS or MOOC platform). Numerous technologies have been used to support students in their learning processes in Education 3.0, such as internet-based CSCL, augmented reality, adaptive learning, intelligent tutoring systems, gamification, etc.

We arrive now to Education 4.0, which we define as being enabled by machine learning [9]. Some might say that machine learning is still software and therefore does not qualify to be called a new revolution. However, computing takes input data and some rules (the algorithm) to get output data, whereas with machine learning it is the opposite: with (lots of) data we get the rules. We are presently just scratching the surface of what is possible with learning analytics [10]. The way is opened to learn how students learn and how the learning can be adapted to each individual student. The opportunities are great, although they come with ethical challenges as well [11].

II. CLOUD COMPUTING

The advent of MOOC platforms and variants have shown the world that technology had a lot of potential that was not yet harnessed. What do platforms like Khan Academy, edX, or Coursera have in common? For us, the essence is the deployment of cloud computing for educational purposes.

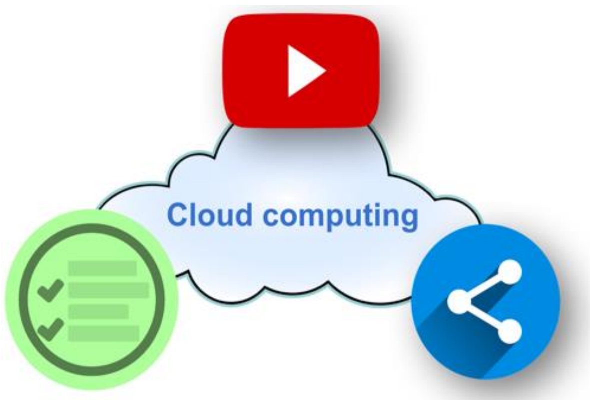

Figure 3: Cloud computing as a basis of educational technology of the last decade

On top of it, there are three main components (see Figure 3):

- Short videos for explanation of concepts
- Interactive quizzes for brain training
- Forums for interaction among students and with faculty.

III. MACHINE LEARNING

Machine learning techniques can be applied in education with different purposes, e.g., to adapt the learning process providing different personalized resources, to create a dialogue with the student providing useful feedback, to form groups of students, to calculate useful higher-level indicators from low-level data or to predict different future behaviors.

Machine learning techniques can try to imitate some human behaviors as these can be modelled to improve the learning process. In addition, machine learning techniques can go further to achieve aspects that human teachers could not achieve so efficiently e.g., applying complex models for skill modelling [12] or predicting students' performance (grades)[13].

In distributed Internet of Things (IoT) scenarios, data from different sources can be collected and analyzed in an integrated way. Different interoperability issues need to be solved: at a format level, so that learner events could be collected with a common format (specifications such as xAPI can be considered) and at a semantic level, so that similar indicators, visualizations, etc. can be defined when combining data from different platforms where their meaning might differ.

Interactions from a web learning platform, a voice assistant or an external third-party e-learning service should be integrated. At a format level, xAPI is probably the most extended specification at the moment. But there are other possible specifications. Most of them enable to represent the different events as "subject-verb-object" and add additional information, such as the timestamp or the context, where the subject is the learner that is interacting, the verb is the type of action and the object is the educational resource where the user made the action. This type of format enables to join data from different sources to be analyzed as a whole.

At a semantic level, e.g., one platform can allow one attempt to exercises, another platform three attempts, another platform attempts until correct resolution, or without limit in the maximum number of attempts. This implies that if we calculate the number of attempts in an exercise the interpretation should be different in every platform or there should be indicators that can be in one platform but not in the others. This issue can be extended for the definition of indicators when we use multiple sources and can also be formulated for the visualizations. There is a need for some common framework to enable different interoperability at a semantic level when combining different sources.

All in all, three key topics related to machine learning are discussed next as the basis for Education 4.0, and as an evolution of the three main components of the use of cloud computing for educational purposes in Education 3.0 (see Figure 4): (1) *mixed realities*, as an evolution of educational videos; 2) *multimodal interaction* as an evolution of interactive activities; and 3) *mixed social networks* as an evolution of traditional social tools for students and teacher-student communication.

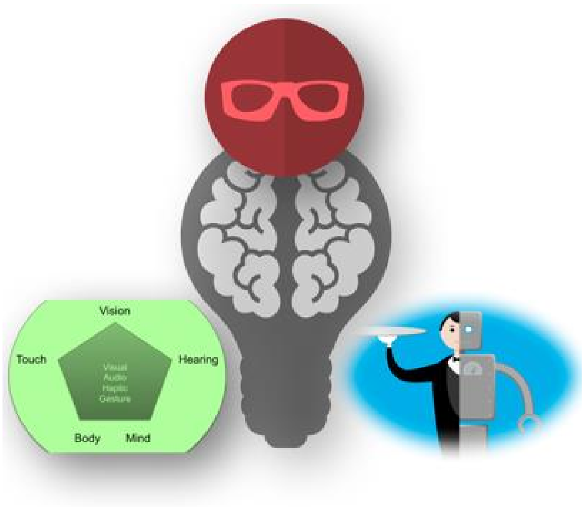

Figure 4: Machine learning as a basis of educational technology of the next decade

IV. MIXED REALITIES

Mixed realities allow students' interaction with digital objects taking advantage on the one hand, of immersion and contextualization provided by the real environment and, in the other hand, the personalization that can be achieved thanks to the virtual or digital environment. For students, learning activities in these mixed environments promote positive psychological emotions that help the learning processes. For educators, mixed realities allow better monitoring of learning and open possibilities for guiding students through learning processes.

Beside these affordances, mixed realities are cheaper to deploy than their counterparts: 3D virtual environments. which require a complete digitalization of learning environments that sometimes do not look as realist as students demand. The real world can be used as the scenario where pertinent activities might be performed by students. Additionally, the use of a real environment has the advantage of facilitating the immersion in learning activities.

Mixed realities can be used to deploy learning activities where students might discover by themselves through interactions new knowledge, new abilities, new competencies. This active way of learning has been proved to be more motivating and engaging for students, fosters concentration, and improves learning outcomes.

In order to deploy worthwhile learning activities, it is necessary to design workflows for students to follow. These workflows should be driven both by students' interactions with the digital objects provided and by the personalization that the learning environment can infer from student previously known data. These workflows can be easily integrated into the mixed learning environment.

V. MULTIMODAL INTERACTION

To many, voice assistants represent the next step after web sites and mobile apps, and their use in education, although yet to be explored, has a great potential.

One of the main objectives of human-computer interaction is to make user interaction more human. The inclusion of voice assistants enables a new way of communication between computers and humans, i.e. though the voice (and natural language). Speaking is a human activity from long ago and the inclusion of devices that can implement voice recognition enables a new way of communication with computers.

The inclusion of the voice as a channel of communication with computers does not necessarily entail new e-learning functionalities but a new form of interaction. The same functionality can be provided with voice or with text, since one can be translated into the other: same functionality but two interfaces.

The use of voice assistants has several important advantages which may lead to learners preferring them: 1) communication through voice and natural language is easier, more straightforward, intuitive and rewarding; 2) speaking is typically faster than writing, which means a more efficient communication. This is especially true with people whoare not used to new technologies, but that could get used to them though the mediation of voice assistants. There is no need to learn how to use a computer or smartphone, just to talk with a voice assistant as if it was another person. Applications based on voice assistants can facilitate navigation through the different menus or the configuration of different options just though voice commands. In addition, learners might be doing other activities (e.g., in-house activities) and at the same time interacting with the voice assistant in a natural way, which is more complicated with other text user interfaces that require more attention.

There are also several important challenges, however, with the introduction of voice assistants. The first challenge is voice recognition. The assistant should be able to recognize different voices with different tones, distances, etc. In some occasions, this voice recognition can fail, and the learner may need to repeat the instructions or commands several times. The second challenge is dialogue interaction. Ideally, the voice assistant should have the proper intelligence to talk in a complete dialogue with the learner. Nevertheless, in reality the interaction is normally restricted to some predefined statements. Although there are already dialogue tutors that can adapt and respond to multiple statements and this can be replicated in a voice interface, this artificial intelligence is not so powerful as another person speaking yet. Therefore, the different possible statements should be clear for learners so that they do not get frustrated. The third challenge is that there should be a clear differentiation between the possible voice statements for the learner interactions with an application and the voice statements for navigation into the different menus of the application.

Following a distributed service-oriented e-learning architecture, in which learners consume e-learning facilities from different platforms and services, voice assistant applications can be integrated as one of these services. They can be also seen as digital sensors in an IoT learning scenario. The information from voice assistants (i.e. voice interactions of the learners) can be retrieved, integrated with other different e-learning components and used in combination.

Our research group has started to design and implement voice assistants for educational purposes. The first prototype of JavaPAL [14][15] has already been released. JavaPAL is a question & answer application for solving Java exercises extracted from several MOOCs on this topic. Students receive questions and answer them using a voice interface.

VI. MIXED SOCIAL NETWORKS

Social interaction is an essential component of the learning experience. In face-to-face educational settings, this interaction is facilitated through the physical contact of students. In virtual educational settings, physical interaction is replaced by other forms of communications supported by technology, such as forums (as a form of asynchronous communication) or videoconferences (as a form of synchronous communication) [16]. In both face-to-face and virtual educational settings teachers can foster social interaction by implementing collaborative activities [17].

In MOOCs, given the large number of students, asynchronous communication is preferred (both among students and with the teacher), generally with a preference for the use of the course forum over other social networks, such as Facebook or Twitter [18][19]. However, the large number of forum messages in MOOCs sometimes hinders the learning experience in several ways. On the one hand, learners sometimes complain that they do not receive answers in a reasonable time to questions that may be critical to advance in the course. On the other hand, teachers find it difficult to separate the wheat from the chaff by identifying those messages that are critical and require urgent attention. In order to alleviate these problems, methodologies and tools, such as 3S and LATƎS [20], have been proposed to help humans digest the large number of messages, and understand the social interactions that occur in MOOCs.

Precisely in a context of abundance of data in an educational environment, as is the case of social networks in an MOOC, is where artificial intelligence and machine learning can be of great help. Forum messages can be analyzed to automatically detect patterns in students' behaviors. For example, authors in [21] concluded that it is possible to use unsupervised machine learning models initially developed for synchronous conversations to understand asynchronous discussions in MOOC forums. Authors in [22] developed algorithms for keyword extraction and relevance-ranking of discussion threads, which were shown effective to analyze the forums in several MOOCs deployed in Coursera. Authors in [23] analyzed students' cognitively relevant behaviors in a MOOC discussion forum, including the relationship between the quantity and quality of the messages posted and learning gains, and proposed a machine learning model to predict these behaviors. Finally, authors in [24] compared supervised and unsupervised machine learning algorithms to carry out a sentiment analysis with the messages published by learners in a MOOC forum. Although this work only focused in establishing the polarity of the messages (positive, negative and neutral), it is a first step towards identifying more complex human emotions in learners, such as excitement, frustration or boredom.

One step forward in the humanization of discussions in social networks in cases where the teacher does not have the capacity to solve all the questions (as in the case of MOOCs), is the use of virtual teaching assistants. For example, Georgia Institute of Technology has extensive experience in the use of virtual teaching assistants in course forums [25][26]. They first built a virtual teaching assistant in 2015, called Jill Watson, using IBM Watson APIs [27], to support forum discussion in an online course on Knowledge-Based Artificial Intelligence. Subsequent versions of Jill Watson were built from scratch, using open-source external library, and had different names as teaching assistants (for a more "humanization") in different courses: Ian Braun, Stacy Sisko, Cassidy Kimball, Liz Duncan, etc. [25]. Interestingly, learners' reaction to the use of virtual teaching assistants in online discussion forums were "uniformly and overwhelmingly positive" [25].

All in all, the use of machine learning algorithms and artificial intelligence, together with a traditional supervision of the course forum, is intended to enrich the learning experience in online educational settings. Nevertheless, several relevant research questions arise: (1) do students really improve their performance in the course thanks to the virtual teaching assistant? (2) do teachers really reduce their workload for not having to answer so many questions (being able to dedicate the time gained, for example, to improving the course contents)? (3) may these isolated experiments be replicated in other learning contexts, with different learner populations and in other areas of knowledge? (4) may teachers become unaware of how the technology that helps them actually works? (5) what are the ethical implications of using a virtual teaching assistant to support learners in a course discussion forum?

VII. Closing the Loop

The advent of this machine learning and deep learning education is strongly based (as for any other domain) on the availability of data [28]. Education 3.0, enabled by internet and cloud computing, shifted the focus from traditional face-to-face settings to online environments. Additionally, such online environments facilitate data gathering and collection. As the availability of data is one critical factor for training the learning models on which education 4.0 is based, it is no wonder that most research initiatives and efforts have been focusing on online environments, with particular attention to MOOCs, but also to learning management systems or intelligent tutoring systems.

In contrast, little attention has been paid to bringing the data-driven perspective into the face-to-face classroom. As discussed in previous sections, intelligent support for content adaptation, collaboration and interaction, etc. are emergent research areas with plenty of activity in the literature for the online context. However, we believe that such processes in the face-to-face classroom can also benefit from the tools developed for and the lessons learned from the online world.

Nevertheless, important challenges arise which jeopardize such application. The difficulties related to gathering data in a context which is not usually mediated by technology, are the most immediate ones. An additional potential problem can be the volume of data, given that online educational settings tend to be more massive than face-to-face ones. Fighting these challenges should be the next step for closing the loop and bringing the education 4.0 technologies back into the traditional educational context.

VIII. Conclusion

In the last decade, we have seen how apart from face-to-face teaching, pure online education has been promoted with models like MOOCs. Although MOOCs have filled a gap, it is clear that something important was missing: the near human touch. With the latest technological developments (see Figure 5) we are combining the best of both worlds. Mixed reality allows us to see real physical objects together with digital ones. Multimodal interaction allows us to interact with computers in ways that are more natural to humans, such a voice or touch. Finally, we can have engaging conversations not just with humans but also with AI bots or combinations of partners of both kinds. Technology has become more human and tries to drive interactions that are indistinguishable from human ones.

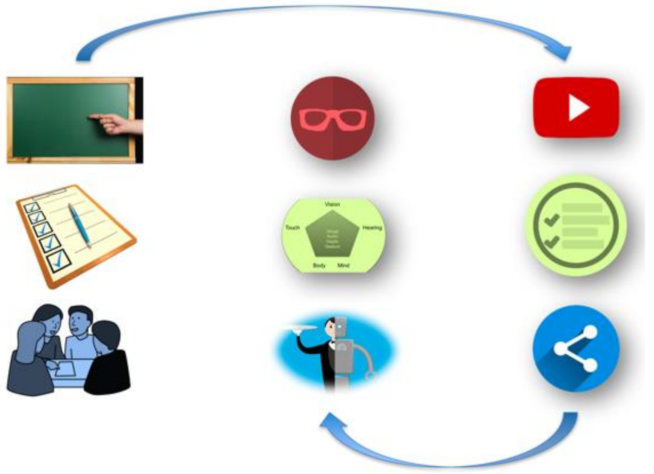

Figure 5: From the purely physical to the purely digital and then to the golden ground of physical space where humans feel at home but with digital support

Technology has got closer to humans, allowing the power of digital technology to underpin activity in the physical space. Together with all the opportunities that this provides, comes all the potential dangers arising from unethical use and exploitation of the data collected. A great opportunity, but also a great challenge.

ACKNOWLEDGMENT

The authors would like to primarily acknowledge the support of the eMadrid Network, which is funded by the Madrid Regional Government (Comunidad de Madrid) with grant No. S2018/TCS-4307. This work has also received partial support from FEDER/Ministerio de Ciencia, Innovación y Universidades – Agencia Estatal de Investigación through Project RESET (TIN2014-53199-C3-1-R) and Project Smartlet (TIN2017-85179-C3-1-R). Partial support has also been received from the European Commission through Erasmus+ projects, in particular, projects COMPASS (*Composing Lifelong Learning Oppor-tunity Pathways through Standards-based Services*, 2015-1-EL01-KA203-014033), COMPETEN-SEA (*Capacity to Organize Massive Public Educational Opportunities in Universities in Southeast Asia,* 574212-EPP-1-2016-1-NL-EPPKA2-CBHE-JP), LALA (*Building Capacity to use Learning Analytics to Improve Higher Education in Latin America*, 586120-EPP-1-2017-1-ES-EPPKA2-CBHE-JP), and InnovaT (*Innovative Teaching across Continents: Universities from Europe, Chile, and Peru on an Expedition*, 598758-EPP-1-2018-1-AT-EPPKA2-CBHE-JP). UNESCO Chair "Scalable Digital Education for All" at Universidad Carlos III de Madrid is also gratefully acknowledged.

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