International Journal of Engineering Education Vol. 36, No. 6, pp. 1740–1751, 2020
Printed in Great Britain

0949-149X/91 $3.00+0.00

Artificial Intelligence Aided Engineering Education: State of the Art, Potentials and Challenges*

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Artificial intelligence (AI) is already starting to transform the way engineering systems are conceived, designed and managed, helping to maximize the chances of successfully achieving their goals. Engineering science, technology and research clearly benefit from AI and engineering educators should be able to make students aware of its potentials, teach them the necessary fundamentals of this field of study and guide them through the application of these algorithms and technologies to the development of real engineering projects, as necessary aspects in modern engineering programmes of study. However, the more relevant impact of artificial intelligence in engineering education goes beyond the application of a set of novel resources to solving specific engineering problems: In fact, the concept of ''artificial intelligence-aided engineering education'' refers to utilizing artificial intelligence techniques and resources for improving the teaching-learning process in higher education, especially in connection with scientific-technological studies. In this study, we concentrate on how AI techniques can support the teaching-learning process in engineering and we describe how AI can be swiftly introduced into any engineering programme. We also analyze the potential impact of AI on improving the overall operation of universities, as extremely complex systems managing myriads of data and countless processes and interactions.

Keywords: artificial intelligence; engineering education; project-based learning; service learning; optimization of resources; ethical issues

1. Introduction

Artificial intelligence (AI) is already helping several types of machines and engineering systems to maximize the chances of successfully achieving their goals. This has led in the last decade to fundamental transformations in a wide range of industrial sectors and economic activities and played a fundamental role in the birth of innovative paradigms, such as ''Industry 4.0'' [1], first in Germany and then spread throughout the whole European Union, and of ''Society 5.0'' [2] in Japan, among other transformations with global impact.

Engineering science, technology and research benefit from artificial intelligence, as can be clearly understood from recent innovations linked to: autonomous cars, collaborative robots, unmanned aircraft systems, self-supervised manufacturing systems, management of big amounts of data, optimization of machines and even design of new materials. Consequently, engineering educators should be able to make students aware of the potentials of artificial intelligence, teach them the necessary fundamentals of this field of study and guide them through the application of these algorithms and technologies to the development of real engineering projects, as necessary aspects in modern engineering programmes of study.

However, the more relevant impact of artificial intelligence in engineering education goes beyond the application of a set of novel resources to solving specific engineering problems: In fact, the concept of ''artificial intelligence-aided engineering education'' refers to taking benefit of artificial intelligence techniques and resources for improving the whole teaching-learning process in higher education, especially in connection with scientific-technological studies. Implications involve all areas of educational practice, from planning and organization of teaching programmes and courses, through implementation and tracing, towards final assessment of learning results and outcomes.

Thanks to artificial intelligence-aided engineering education we may well be living the dawn of a new era of more effective, efficient, accessible and inclusive technical universities. If adequately deployed, AI may promote a more sustainable education and support the concept of ''engineering education for all''. Among pioneering reports and studies highlighting the potential of AI for education, it is important to highlight: (1) ''Artificial intelligence in education: challenges and opportunities for sustainable development'', which focuses on the potential of AI for improving learning and equity in connection with the Sustainable Development Goals and the 2030 Agenda (UNESCO) [3]; and (2) ''The impact of artificial intelligence on learning, teaching and education'' from the EU

* Accepted 20 March 2020.

Commission, which analyses the potentials of AI for transforming teaching and learning and highlights the need for related supporting policies [4].

In our study, however, we put the focus on higher education and on the engineering fields, domains that can be also importantly transformed by the emergence of AI. Until now, training on AI and related engineering applications has been mainly achieved through specialized courses or programmes, usually in connection with research tasks and PhD studies [5] within dedicated research centers. Analyzing the most adequate structure of topics for such comprehensive programmes and courses is beyond the aims of current paper, as there are many examples of good practices and initiatives for training the engineers of the future in the fundamentals of AI and the application of AI methods to solving engineering problems and optimizing engineering systems [6].

Here we concentrate on how AI techniques can support the teaching-learning process in engineering, helping to promote a more personalized education, to enhance learning, to aid with curricular planning and to enhance processes like student assessment. In addition, we describe how AI can be swiftly introduced into any engineering programme, to provide students with the fundamentals of AI and illustrate their potential applications in their concrete fields of specialization, by means of innovative pedagogical actuations and active learning experiences, such as project-based learning, service learning, and challenge-based educational activities, among others. Furthermore, we analyze the potential impacts of AI to improve, not just the teaching-learning experiences and processes, but also the overall operation of universities as extremely complex systems managing myriads of data: ''AI-assisted (technical) universities'' are a relevant component within the new concept of ''AI-aided engineering education''. Main challenges for achieving a more efficient and sustainable engineering education through the application of AI principles are finally discussed and analyzed.

The whole study is structured as shown in the roadmap proposed in Fig. 1 for the period 2002–2030, according to authors' expectations, in connection with scientific, technological and educational goals that should progress in parallel to the Agenda 2030 of United Nations. First, the state-of-the-art is analyzed, covering experiences showing AI as supporting tool for educational practice and pioneering cases of teaching-learning experiences involving AI. Then, research areas paving the path towards intelligent universities are presented and main challenges for sustainably developing and exploiting the potentials of AI for engineering education are analyzed.

The roadmap scheme is coincident with the structure and sections of present study.

2. AI as a Tool for Supporting the Teaching-Learning Process

AI can contribute to revolutionizing the ongoing educational paradigm. As AI educational solutions continue to mature, they may help to solve some challenges in the educational processes. AI could be applied throughout the whole teaching/learning process: Professors find in their students a high diversity and each student requires different kinds

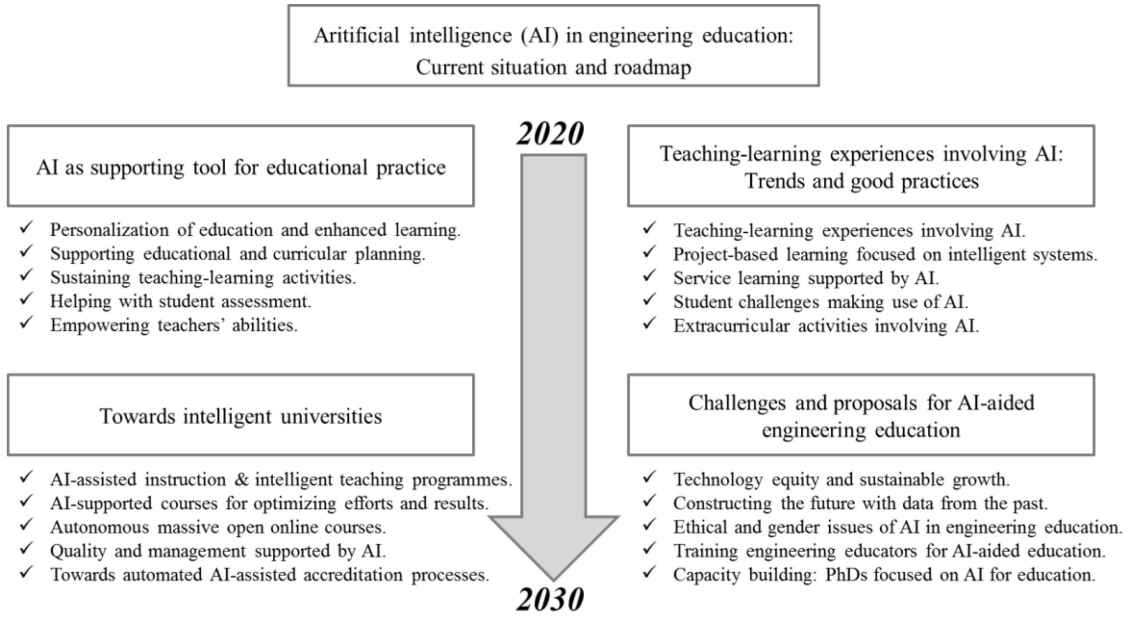

Fig. 1. Artificial intelligence in engineering education: current situation and roadmap.

of encouragement to improve their academic results. AI could complement the professors' efforts to personalize education and enhance learning. Time spent in administrative tasks could be reduced and the planning could flexible to be adapted to every student. The teaching-learning process would be reinforced with the automatization of some elements and the students' data would allow a quality assessment. AI can transform the education. However, professors must empower their teaching abilities and combine them with AI to get the best outcome for students.

2.1 Artificial Intelligence for Personalizing Education and Enhancing Learning

Student diversity is a persistent challenge that professors face daily, even more in engineering education. Learning management systems and other educational platforms collect a large amount of data about students, although these data are in most cases stored without being further considered. AI systems could analyze these data and detect students' difficulties. In many cases, these difficulties could be solved redirecting students to specific contents. In engineering education, the diversity of students' backgrounds is wide, and there is not a unique solution for teaching. Data analysis could predict dropout risk and offer students personalized resources to ease learning and reduce the gap with the expected access level [7]. Each professor has a teaching style and each student has a learning style. When these teaching and learning styles are not aligned problems tend to appear. AI applications for education are being developed including AI mentors with a teaching style that can be adapted to student learning style. Tutoring and support outside the classroom could be automatized and the answers to the students' questions could analyze facial expressions of the students to ensure adequate comprehension. Adaptive learning is not a recent term, however with the AI is being empowered. There are many solutions like programs, simulations, games and other software, which respond to the needs of the student. These applications manage the learning process and students can review the contents they have not mastered and work at their own pace. AI goes beyond so that the idea of customizing curriculum, for every student's needs, will come true.

2.2 Artificial Intelligence for Supporting Educational and Curricular Planning

Educational planning and scheduling are complex tasks. Educators make changes every course seeking to enhance results with their new students. However, each group is different, and the same planning could work fine with one group and not so much with other. AI helps to make better planning. For example, establishing the probability of students' success based on their preferences and professions [8]. Students' satisfaction is highly conditioned by their initial expectations. AI can also help students with course enrollment process with recommending systems based on the students' previous background. Huang et al. [9] show in their research a case of study collecting data of personnel training in China Motor Corporation for mining analysis and classification. Based on the results, the authors proposed a suitable model for educational training through a better planning of the courses. Blagojević and Micić [10] introduce an application of artificial neural networks in order to support curriculum planning and advance educational processes at the level of higher education. Application results could have a significant effect on curriculum planning thus supporting the educational process, as professors could adapt their courses according to students' prior knowledge.

2.3 Artificial Intelligence for Sustaining Teaching-Learning Activities

There are many studies about the influence of data mining analytics on the teaching and learning processes [11, 12]. These analyses began more than twenty years ago with the common purpose of continuous improvement. Until AI arrived, results have been interpreted by professors to enhance the process. With AI, a more exhaustive analysis can be accomplished and immediate decisions can be triggered. For example, Coursera analyses students' responses and if they detect a massive failure, the system alerts the teacher and gives future students more detailed info. These systems offer immediate feedback to students that help to understand a concept and remember it correctly.

Is it possible that AI replaces professor in some parts of the teaching and learning process? This question opens a complex discussion about a new pedagogical philosophy because it is not the same education as solutions provided by algorithms [13]. However, some studies show little steps towards AI professors. An example is offered in an artificial intelligence program at Georgia Tech in the USA. Students nominated Jill Watson for a teacher award because of his high dedication along the course. The surprise at the end of the course was finding out that Jill Watson was not a real person, but a teacher bot, a virtual teaching assistant based on the IBM's Watson platform. The teacher bot wrote the class directly with a 97% of adequate responses. At the end of the semester, it was able to answer most routine questions asked by students. The goal of the project is that the virtual teaching assistant may answer 40 percent of all questions [14].

2.4 Artificial Intelligence for helping with Student Assessment

Assessment tasks are often long and tedious when professors have a high number of students and usually not very formative. Frequently, professors find in the exams the same mistakes and AI could reduce assessment time considerably. There are many studies about self-assessment and it is now possible for professors to automate grading using multiple-choice and fill-in-the-blank testing.

Today, automatic essay-grading is in its infancy; however, AI assessment system will collect data about students' achievements, their emotional states or motivations. These data will be rich information for professors because they could adapt their teaching according to the students' approach to learning and motivate students allowing them to track their progress, what reflects on their learning [15]. Due to subjective and objective reasons, a precise assessment requires high dedication. Automatic assessment can ease this labor and offer professors a more consistent students' assessment. All works could be evaluated based on the same criteria, and marks would be detailed instantly to the students [16].

Recent studies have implemented an Artificial Intelligence Teaching System (AITS), which automatically assess student performance [17]. The system assists students in learning and tutors in teaching search algorithms. The study shows that the system has been contrasted with 400 assessments and in a high percentage the assessment is very similar to the actual tutors' results. Assessment assisted by AI may promote a new generation of more active students, because they can be aware of their own learning, in more accurate and timely manner, and hence act more proactively towards better results and enhanced learning outcomes.

2.5 Artificial Intelligence for Empowering Teachers' Abilities

The role of the professor has evolved over the years and quite change in the last two-three decades with the implementation of more active learning methods worldwide, especially in engineering education. Technology has undoubtedly empowered teacher abilities. If we compare the role of the professor in a traditional class with the role in a ''flipped'' classroom, it is clearly different. Both have the main purpose of promoting students' learning. However, the second professor requires many different skills to accomplish the objective. With the AI, professor abilities will be enhanced, but the role of the professor will shift even more to that of a facilitator. At the University of Staffordshire, Beacon is a chatbot introduced as a new digital friend [18]. On the other hand, Ada is another chatbot developed in Bolton College based on IBM Watson [19]. Both of them are available 24/7 and they can offer students personalized answers about their schedules, attendance, grade profiles, and whether their academic performing is good. With this information, professors have real-time data about their students, and they may delegate most of the administrative tasks. Professors will supplement AI lessons, assist students who are struggling to pass, and provide human interaction and hands-on experiences for students.

Most of the studies analyze how the role of the professors may enhance efficiency via the automation of teaching. However, Sian Bayne shows in his findings that the current perspective about teacher bots is driven by a productivity-oriented effectiveness and not by pedagogical reasoning [20], which should be a sign of alarm regarding AI and education. In his study, Bayne used a teacher bot in a MOOC with more than 90,000 students at the University of Edinburgh. The bot answered students by twitter and it was not highly effective, however it was able to prompt students to engage with more questions. AI may be of extraordinary support for professors. Nevertheless, ethical, social and gender considerations surrounding AI must be explored and considered for future implementations in the field of AI-assisted engineering education. Some studies, like the taken by the Open University UK, have offered eight principles in order to protect all stakeholders [21].

3. Innovative Teaching-Learning Experiences involving AI: Trends and Good Practices

3.1 Teaching-Learning Experiences Involving Artificial Intelligence

The teaching and learning process has been deeply transformed by the digital revolution along the years. The advent of the AI can be considered a turning point. Technology has become an essential everyday tool and professors have improved their teaching practices. However, the new AI paradigm presents an important difference because AI is not only a tool along the teaching-learning process, but can partly replace professors in this process. One of the main contributions of AI to education is the possibility of offering students a more personalized learning, efficient and sustainable. Before the learning process, AI could collect data about students, in order to modify the planning and make contents more adequate to students' profiles [10]. AI can contribute to finding the most effective teaching method for professors and learning process for

students. For professors, AI tools can help to grant universal access to their classrooms.

As an example, students who speak different languages or might have visual or hearing limitations have found in the Presentation Translator a solution. This AI tool is a free plugin for PowerPoint that creates real-time subtitles of what the teacher is saying and displays them below the presentation [22]. Another example can be analyzed at the Tacoma Public School, where Microsoft equipped teachers and administrators with tools to identify students that are likely to disengage and ultimately drop out. As a result, the district has already registered an improvement in graduation rates from 55% in 2010 to 82.6% in 2016 [23].

AI has been applied along the teaching-learning process. Most of the studies could be classified according the major parts of the educational process: customize content, innovative teaching methods, technology enhanced assessment and communication between student and lecturer [24]. As we saw previously, the innovative teaching methods based on AI are focused on personalized learning and customized content. Each student has a different pace of learning and AI provides a possibility to avoid this problem by personalized learning [25]. Another innovative teaching method is using robotics. Robots developed with AI can teach children STEAM (Science Technology Engineering Art Mathematics) disciplines, even students who may have behavioral or psychological problems due to their social skills. Robots will enable us to build real environments since initial stages of education [26]. In the communication process, intelligent tutoring systems (ITS) are developed to give appropriate and targeted feedback to students [27]. These systems have been used for years in different disciplines like physics, mathematics, language, computer science, medicine, and others [24]. The main contribution of ITS is a better student performance because they have the capability to interact with students step by step, rather than giving a final feedback at the end of the task.

3.2 Project-Based Learning Focused on Intelligent and Autonomous Engineering Systems

Problem-based learning (PBL), project-based learning (PBL/PjBL), experiential learning, game-based learning, learning through play, learning in collaborative project and environments, among others, are different versions of highly formative and integrative or holistic learning experiences that place students in the center of the teaching-learning process, in accordance with a desire for a more comprehensive training for the 21st Century, fostering knowledge, abilities and skills, especially in engineering education [28]. These methodologies have proven their success in all fields of engineering and, if the proposed topics for students' projects and their boundary conditions are slightly modified, they can also serve to expand the applications of AI.

For instance, the formulation of the problem to solve can highlight that students should develop a product or process for solving the problem, in which AI plays a relevant role. Projects can be connected to intelligent robots, autonomous drones, smart vehicles, self-sufficient buildings, affective medical technologies, self-monitoring production and assembly lines, for solving mobility, health, manufacturing or environmental issues, among others. In the "Industriales INGENIA" program within the master in Industrial Engineering at the Universidad Politécnica de Madrid, we can find an example of this methodology. Every year, and based in PBL, students' teams with different profiles live the complete process of design, manufacture and validation of novel medical devices and analyze their economic viability. This experience promotes the entrepreneur spirit and brings students near to jobs in a digital society and some of the projects developed have resorted to artificial intelligence, including medical devices with improved diagnostic decisions [29]. The PBL learning methodology helps students in the search for real problems, developing complex solutions and generating synergies among the team members. The main role of the professor is advising, guiding and motivating the students through the project. Some studies highlight the relevance of project-based learning for the rise of artificial intelligence [30]. With this methodology, students have the opportunity to develop professional skills, in a leadership environment, teamwork, proactivity and innovation.

3.3 Service-Learning Projects Supported by Artificial Intelligence

Service-learning was defined by Jacoby as "a form of experiential education, in which students engage in activities that address human and community needs together with structured opportunities for reflection designed to achieve desired learning outcomes" [31] and it is clearly connected to challenge-based and project-based learning, which has given also rise to the term "project-based service-learning" educational experiences. When additionally connected with open-innovation and with collaborative engineering design methods, these models lead to the "open-source & collaborative project-based learning" or OSC-PBL approach [32]. Due to the appropriateness of AI for predicting the behavior of extremely complex systems, especially those with several inputs and outputs and when massive data and non-linearities are involved, several topics

for project-based service learning educational experiences can be proposed, which can again help to enlarge the areas of application of AI. Optimizing traffic light signals in a city, solving problems linked to waiting lists in hospitals, studying the pollution in cities, are among the topics that can be proposed for students' service learning projects. Such experiences go beyond industrial applications and enter the realm of the tertiary sector, in which AI can play a very special role in the near future. Service learning has become an important movement, especially in undergraduate education: Community service integrated into a study plan enables students to connect thought and feeling, creating a context in which students can explore how they feel about what they are thinking and what they think about how they feel. These programs have shown to contribute to a greater sense of civic responsibility and are a vehicle to promote the skills and knowledge needed for leadership [33]. Engineering students participate in research projects assisting in the development and implementation of courses, workshops and summer camps for undergraduate students. Organizations like the Institute for Research in Intelligent Systems (IRIS) allow students to collaborate in service-learning. This institute is focused on the development and integration of accessible intelligent systems research and technologies for use in community and industry. These experiences in lesson planning, presentation and demonstration offer students opportunities to develop their technical skills, as well as communication and interpersonal skills [34].

3.4 Student Challenges making use of Artificial Intelligence

Another way to involve students in AI-related formative experiences and to motivate them acquire the basic principles and apply its methods to real engineering problems is the promotion of student challenges, for designing ''intelligent'' products, processes and engineering systems in general. International challenges, such as Formula SAE/Student in mechanical engineering field, Solar Decathlon in Architecture, CanSat competitions in aeronautics, Cybertech, FIRST Tech and LEGO® challenges in robotics, UBORA design contests in biomedical engineering, among others [35], prove to be highly enjoyable and motivating learning experiences, in which students acquire and apply technical skills and foster their soft skills (creativity, teamwork, oral and written communication), especially if performed in an international context. In many cases, the challenges are just extracurricular activities, but it is also possible to assess them and give them a value in credits, as part of the programmes of study.

In the AI field, some of the most important companies are sponsoring challenges to benefit from open-innovation approaches, including Microsoft with the ''AI for Good Idea Challenge'', IBM with the ''IBM Watson AI Prize'', Samsung with the ''AI Challenges and Hackathons'' and Google AI with the ''Impact Challenge''. The ''General AI Challenge'' by GoodAI, the ''Animal-AI Olympics'' and the ''World Artificial Intelligence Competition for Youth (WAICY)'' are also noteworthy, the latter focusing even on primary education and high-school students. In all cases the contests seek for AI-based solutions for solving societal needs and are typically open to scientists, students and amateur participants. Following these examples, universities worldwide or consortia of universities could sponsor challenges on AI for solving problems in different fields of engineering linked to societal needs and consider participation in such challenges part of the formative programmes, recognizing participation with, for instance, 1 credit for every 25–30 hours of student dedication (according to the ECTS models). Some studies recommend the ''Project and Practice Centered Learning'' methodology for AI teaching because it is important that students are comprehensively trained to have both high-level vision and ground-touch skills, so that they not only can see an AI entire system but also build up a fully functional real-world targeted system piece by piece [36].

In addition, such challenges could be hybridized with or form part of more comprehensive and holistic project-based and service-learning experiences. Topics for the challenges may range from smart cities to autonomous vehicles, from intelligent products for day-to-day life to smart medical devices. If adequately mentored and supported by formal lessons on the fundamentals and applications of AI, these challenges can turn out to be very complete ''CDIO'' (Conceive-Design-Implement-Operate) experiences and highly formative for students (and professors) involved.

3.5 Extracurricular Activities involving Artificial Intelligence

Apart from challenges, which may be curricular or extracurricular, the promotion of other types of extracurricular activities in the AI field may be also a way of supporting the expansion and impacts of these emergent techniques. Among them, the organization of summer schools, the development of internships in research departments and companies with a focus on AI or the development of conferences, seminars, workshops and fairs, to

illustrate the university communities about the possibilities of AI, are some of the more remarkable extracurricular possibilities.

Regarding summer schools, some companies are already sponsoring learning experiences, such as the ''Autodesk Artificial Intelligence (AI) for Engineering Summer School 2019'', an event that has brought together a group of engineering graduate students and industry professionals to acquire expertise in state-of-the-art AI methods and techniques, with the focus on deep learning and reinforcement learning. The ''AI Summer School'' organized in Singapore in 2019 and the ''Hello AI Summer School'' organized in Budapest and Barcelona in 2019 (and focused on AI for health with funding from EIT Health) are also interesting examples of how universities, research centers and companies may synergize for developing interesting teaching-learning experiences. Resorting to the organization of extracurricular summer schools and satellite events on AI is a good option for rapidly offering students preliminary solutions for their interests in this field, before progressively incorporating these topics into the formal programmes and engineering curricula.

4. Towards Intelligent and Autonomous Technical Universities

4.1 Computer-Assisted Instruction and Intelligent Teaching Programs

Future educators will surely find in the AI field a relevant support to enhance their teaching efficiency. AI applications collect data in real-time to personalize learning to students according to their performance and present students' traces to professors for making decisions. With MOOCs (Massive Open Online Courses) arrival, large datasets detailing how students interact on forums, work in assignments, view lectures, and final grade are generated [37]. Such information will allow generating AI algorithms used by intelligent tutoring systems (ITS) with teaching and assessment strategies statistically calibrated to match individual student needs and preferences. These analyses of big data will also facilitate more effective predictions of students' performance, and their suitability for post-graduation occupations.

Nonetheless, rigorous studies show that the probability of computerization of education employments is low [38]. AI programs are based on massive data. The probability of students having the same doubt about certain content or the same mistake(s) in an assessment is high. AI algorithms analyze these data and with previous instructions from the professors, students could receive real-time feedback. However, what will happen if a brilliant student proposes an alternative method in their assignment solution? There is a high probability that the system considers it as a wrong solution and the ingenious solution could result unnoticed.

Machines cannot yet replace the creative and diverse perception of the human mind. Recently we could see how Google showed in its translator gender bias pairs, like ''he'' with ''hardworking'' and ''she'' with ''lazy'' among others [39]. It is very important that the systems will be programmed properly, in order to avoid any biases towards any students based on gender, race, or socioeconomic status. Teacher bots could meet the primary needs and AI analyses would help professors adding a new perspective to educate students in a better way, by solving critical and systemic issues in education.

4.2 Optimizing Efforts & Enhancing Results: AI-Supported Courses

Education 4.0 has its origin in response to the needs of Industry 4.0: New skills, competencies, planning, teaching and learning methodologies, and assessments are needed to grant flexibility in the new paradigm. To achieve this, AI is necessary for the fourth revolution in the education system. It must be with a strong active presence to get better performance. Education 4.0 has been characterized by blended learning and seven AI driven features as significant challenges: personalized learning process, game-based learning using virtual reality/augmented reality (VR/AR), communities of practice, adaptive technologies, learning analytics, intelligent chat bots and e-assessment [40].

AI can support the entire educational process, from start to finish, contributing to improve results. Most studies are focused on improving student efficiency through personalization of learning or early detection of learning problems with automatic response [41]. Overall, studies are based on the analysis of LMS logs, but others add innovative elements, such as wearables or smart sensors, for self-monitoring of the cognitive state of the student in the learning environment. Wearable gadgets and other smart sensing devices will be applied in the future on the use of modeling students' behavior through monitoring the health factors such as motion, drinking, having a break, temperature and as well as emotional status recognition [42].

In principle, the more technology involved the more information the students will have and the better decisions may be taken. However, we may end up exceeding an ethical line, by reaching states in which the machines will have a high level of information, which must be handled with care. Large organizations, companies and governments are focusing on the problems that may arise in the issue of artificial intelligence ethics to draw

common considerations, practices and frameworks for the future. It is important to reach an agreement to conceptualize and, above all, regulate practices also in education and especially in engineering education, as engineers will set the foundations for the future of AI.

4.3 Autonomous Massive Open Online Courses

MOOCs have found in AI a partner to face many of the challenges they have encountered since their inception. AI applications could encourage students when it is detected that they are going to dropout. They could offer the students a faster progression if they are getting bored or slower and with more content if the course is proving to be too difficult. They could analyze the students' participation in the forums and moderate the course in the right direction identifying the role played by each student. Besides, they could offer a more effective assessment, assessing tasks automatically and even validating peer-reviews. The personalization of the learning is nearest thanks to AI. However, technically there is a long gap to get teaching machines to converse like humans. AI conversational interaction is still an open research challenge today and the cooperation between MOOC platforms making learning behaviour data accessible to AI researchers is needed. Besides, ethical issues must be carefully deliberated before carrying out interactive experiences with students [43].

Introducing AI in MOOCs is not an easy task. Probably, the main reason of AI not having a complete integration is that MOOCs design is based on traditional learning. MOOCs are looking for standardization and not personalization. From contents to assignments, the learning in MOOCs is lineal and students must adapt to these parameters leaving out individuality, creativity or critical thinking. Autonomous massive open online courses should be consequently reinvented.

In order to provide future MOOC students flexibility and customization, the first step is to restructure the learning contents in well-labeled units of knowledge. This strategy is applied to create micro-MOOC, which could be considered building blocks. These blocks could combine in different ways allowing professors to create different learning paths. AI is offering great possibilities to analyze student learning along the learning paths and identify critic points in which students with different backgrounds could need different support [44].

4.4 Continuous Improvement and Management in Universities Supported by AI

Data powered by AI can change how schools find, teach, and support students. Since predicting how many engineers will enroll in the next course [45] to personalizing learning according to their background, AI could ease all administrative tasks, even during the first year, when can be more complex. Universities could plan with more actual information than previous years. There are many mentor programs to welcome students in their first days at university. Relationships are very important, and the experience of the mentors must keep being carried out. However, personal information like schedules, class locations or laboratory requirements could be managed by AI to help students in their initial moments at the university and beyond [18, 19].

During the teaching-learning process, we have already analyzed how AI could transform the current paradigm. Nevertheless, AI could also help students to choose their optional itinerary or intensification paths. The selection process may end up looking a lot like Amazon or Netflix, with a system that recommends the best subjects and programs for students interests.

From the point of view of university management, many processes can be improved by applying AI. Marks recordings, subject reports for accreditation processes and other administrative documents could be self-filled based on the results and available data, only to be reviewed and validated by the professor. In short, any vertical process could be optimized, just like any enterprise that is facing digital transformation. Other more specific processes, such as professor training, could be studied so that depending on the profile of the professor, the system could propose courses to improve their technical and professional skills [46].

4.5 Towards Automated AI-Assisted Accreditation Processes

Administrative tasks are often long and tedious. In the accreditation processes, a large part of the work is devoted to administrative tasks based on the collection and analysis of data. After these analyses, it is possible to conclude with results and improvement points. Through the AI, administrative tasks could be automated, such as the analysis of learning guides or compliance with the rules for admission to the program. With the appropriate interfaces and centralization of data, the corresponding analyses could be accomplished in such a way that the accreditation reports would be automatic. For this, it is necessary that universities become committed to the digitalization of processes, as it is happening in Industry 4.0. With the automation of these processes, quality managers could have real-time information about meeting the different accreditation requirements and their work could focus on solving those problems instead of trying to identify them.

According to Rhea M. Steele [47], Chief Operating Officer for the Council for the Accreditation of Educator Preparation, accreditation systems depend on clearly defined rubrics to help reviewers make decisions about the institution's adequate of meeting standards. AI could help with the quality, as well as with the quantity of the reviews, but the challenge for volunteer reviewers is to approach each organization with true objectivity. In the same way that accreditation agencies currently train peer reviewers, an accreditation AI could be trained using data elements, evidence, rubrics and decisions made by previous peer reviewers. Then, AI could learn and improve together with peer reviewers currently auditing institutions and compare AI recommendations with those of the peer review team for final adjustment. Eventually, AI could provide absolute consistency in the identification of key areas for improvement and of misalignments with the standards.

5. Challenges and Proposals for AI-Aided Engineering Education

5.1 Technology Equity and Sustainable Growth of this New Trend

The excellent UNESCO report on "Artificial intelligence in education: challenges and opportunities for sustainable development" puts forward six fundamental challenges for the sustainable growth of AI in education and for its equitable global impact: (1) the development of comprehensive public policies on AI for sustainable development, (2) ensuring inclusion and equity in AI in education, (3) preparing teachers to understand AI and AI to understand education, (4) developing quality and inclusive data systems, (5) making research on AI in education significant and (6) ethics and transparency in data collection, employment and dissemination. The relevance of dynamic policies for promoting AI impacts on education have been also highlighted elsewhere [3]. All this applies, not only to basic and secondary education, but also to higher education and engineering disciplines, as discussed in some following subsections.

Besides, as regards educational and technological equity, the use of open source approaches to software and hardware projects, which is already transforming product development (and product development education) worldwide (Processing, Wiring, Arduino, UBORA), should be applied to AI-based solutions and systems. In fact, some of the more relevant players in the AI field are already sharing their solutions as open source projects (i.e., Google's TensorFlow open source library and framework for machine learning, IBM's open solutions and development environments or Acumos AI platform, which is part of the LF AI Foundation within The Linux Foundation, among others), which is boosting the sustainable and steady growth of the AI industry.

The future of engineering education, whether supported by AI or not, will for sure rely on collaboration and on sharing engineering solutions, pedagogical tools, results from engineering projects and cases of study, as recent studies have put forward [32].

5.2 Constructing the Future with Data from the past

Most AI-based systems are trained with vast quantities of data, but still mainly with data from past observations, which limits their capability for predicting future scenarios and for driving to radical innovations. Such radical innovations are fundamental in many cases to transform higher education, especially in engineering fields, so as to adapt to the rapid pace of technological progress. Consequently, input from educators is needed (and will probably always be), even if aided by AI tools.

Today's students are different from those of yesterday and will be different from those of tomorrow. The generations change, their contexts condition them and the educational models must be updated. In addition, in the engineering programs, each year the planning is updated in relation to contents, and what was studied years ago is a small part of the current plan. New technologies, new techniques, new discoveries make academic planning very different. Due to these continuous changes, AI applications will not be effective enough if they are based only on the data of a single professor. Data is called, "the oil of the future", and the creation of educational networks to share data will allow better algorithms trained with high student diversity. This wide data collection will reduce mistakes and adapt more quickly to social, technological or educational trends.

5.3 Ethical and Gender Issues of AI in Engineering Education

Much has been written about ethical issues in relation to artificial intelligence and that is the reason why the more relevant players in the AI arena are incorporating experts in ethics to work together with software and hardware developers. These issues have to be considered also when incorporating AI to higher education and, if AI is going to be included as formal topic in common engineering degrees, we should ask ourselves if the incorporation of courses on ethics for engineering degrees worldwide should not be systematically promoted first.

In connection with ethical issues, we should also

make reference to privacy and data management, as AI aided engineering education will mainly work with vast quantities of data, including personal data from students and educators. At the same time, findability, accessibility, interoperability and reusability of data may support the expansion of AI-based solutions for higher education and the progressive approach to educational equity. A good starting point regarding data management for AI systems in education would be the use of "FAIR" data principles [48].

Another well-known issue is that AI tools are subject to gender, social and race stereotypes and prejudices, because in too many cases they are trained with data with gender, social and racial biases. If AI systems (i.e., chatbots, Alexa-like devices, empathetic machines, robots, health affective technologies avatars and virtual assistants) are wrongly trained they may help to maintain such stereotypes and prevent the achievement of educational equity, instead of supporting its achievement. AI is bound to repeating errors of the past if development teams are not diverse enough.

5.4 Training Engineering Educators to Keep Pace with Technological Advances

A fundamental challenge for deploying the potential of AI in engineering education lies on the fact that current generation of engineering professors did not study AI principles and tools, as part of the corpus of their different engineering disciplines. Lifelong learning is necessary for professional development in engineering education and should be supported by actualization courses organized by universities and their departments of educational innovation and centers for pedagogical sciences.

Compromise with lifelong learning should be also encouraged by recognizing it for career development as engineering educator. To date, most courses in lifelong learning programmes at universities focus on pedagogical resources and methods, on common computer software resources, on tools for developing e-learning and b-learning experiences, on basic programming and language skills and on statistics for research practice [46]. Progressively incorporating courses on "AI principles" and on "AI applied to teaching" for educators, as well as focusing on other technological topics within the Industry 4.0 movement, including: big data, cloud computing, augmented reality, cybersecurity, internet of things, advanced simulation and rapid manufacturing tools, all of them importantly interwoven, would be a recommendable practice for increasing the impact of these advances.

5.5 Capacity Building: PhD Training Focused on AI for Engineering and Education

Doctoral training programmes focused on AI applied to education may be also part of the solution for a new generation of educators with expertise in AI principles, tools and applications for pedagogical purposes. To this end, interesting calls, such as the "International Training Network" calls from the "EU Marie Sklodowska-Curie Programme", in which networks of PhD students are trained on a specific field and following innovative doctoral training principles, can be oriented to AI-related R&D topics in connection to higher education. Capacity building may well be the best strategy for supporting a sensible use of AI in engineering education.

6. Conclusions

Artificial intelligence is significantly affecting engineering practice and, therefore, it must have a transformative impact in engineering education. Apart from the need for updating engineering education programmes and course contents, to enable the engineers of the future understand how to use AI principles and methods for their engineering practice, it is important to understand the implications and potentials of AI for reshaping technical universities and constructing a more successful engineering education. Indeed, AI may help to improve several aspects of teaching-learning processes, to enhance education by improving the degree of personalization and the learning outcomes, to optimize overall operation at universities, and to advance towards technological education equity. In this study we have introduced the concept of "artificial intelligence aided engineering education", analyzed the aforementioned potentials and discussed various educational experiences that can benefit from using AI and help AI to deploy its potential for higher education. AI is here to stay and will clearly affect engineering education, in our opinion in a very positive way, if the current discussed challenges are adequately taken into consideration. Capacity building and training of engineering educators in AI-related topics may be a fundamental key to success.

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