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ARTIFICIAL INTELLIGENCE & HIGHER EDUCATION:
Towards Customized Teaching and Learning, and Skills for an AI World of Work

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ABSTRACT
We are living in an era of artificial intelligence (AI). There is wide discussion about and experimentation with the impact of AI on education/higher education. In this paper, we give a discussion of how AI is evolving, explore the ways AI is changing education/higher education, give a concise account of the skills universities need to teach their students to prepare them for an AI world of work, and talk succinctly about the changing nature of jobs and the workforce.

Keywords: Artificial Intelligence, Machine Learning, Deep Learning, Big Data and Data Analytics, Interactive Learning Environments, Blended and Hybrid Learning, MOOCs, Digital Learning, Customized/Personal Learning, Educational Technology, Virtual Reality, Robot Teaching Assistants, Personalized Learning Systems, Cognitive Skills, Technological Skills

The quest is on to create intelligent automation (AI) that can collaborate effectively with people, learn, analyze, self-correct, recognize, make decisions, and outthink the best and the brightest.[1] Big data, information, and computing power play the dominant role in the AI world. Computers best humans in repetitive and predictive tasks; in jobs that rely on computational power, big data, and decisions made based on distinct rules; and in enumeration and evaluation of data. Humans, on the other hand, best machines in experiencing genuine emotions and building relationships; in formulating questions and articulating ideas; in making strategic decisions; and in making products and results to the benefit of humans. In today's AI world, intelligent automation collaborating effectively with humans is stronger than either alone.[2] It is an opportunity for humans to use AI as a tool for enhancing what humans do.

Artificial Intelligence is developing and becoming more commonplace in our daily lives. There are already innumerable examples of AI's widespread adoption including smart phones, voice assistants, autonomous driving technology, home robotics, delivery robots, robots in factories/offices/classes, robots in healthcare/operating theaters/for physical assistance, and online. We are experiencing the transformation of AI in our daily lives, jobs, businesses, and education to better human lives.[3] With the rate technology is developing, further change is inevitable.

When it comes to education and higher education, AI technologies are powerful and well suited to the enrichment of educational objectives. Indeed, the past two decades have seen considerable AI advances in education.[4] As will be discussed, this progress brings opportunities for enhancing teaching and learning efficiency and effectiveness; preparing students for the AI world of work[5]; enhancing student support; improving teacher, faculty, and staff support; streamlining administration in schools, universities, and colleges; and providing education for masses. As with every development, concerns about and challenges in all of these areas are inevitable, and we shall address these, too.

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We all need prepare well for an already present AI world to achieve desired useful outcomes of AI technology, to enhance our own lives, and to enhance the lives of people, their communities, and societies. Higher-education institutions must now produce graduates who can get jobs in the AI world of work — jobs that require AI skills along with human skills, adaptability, and resourcefulness. High-level intellectual skills are required to meet the challenges of the changing nature of the work. There is the need for different learning outcomes focused on the demands of a digital society that is prone to continual change. Change and transformation in education is foreseeable. Higher education, therefore, is searching for ways to respond to the already existing influence of AI on education, across all disciplines and sectors.[6]

Among the most important values of the universities and colleges are:

- thriving freedom of thinking and inquiry, academic skepticism, in-depth understanding, and advancements of knowledge;
- initiative, creativity, and entrepreneurial spirit for graduates;
- the agenda of education/higher education set by schools, universities, and colleges; and
- human-centric ethical norms in the age of AI.

In line with these values, AI is to enhance human thinking and inquiry, augment educational processes, enrich in-depth understanding, advance knowledge, improve knowledge-based decision making, automate administrative tasks, and yield to ethical AI world that is human-centric.

How the AI World is Evolving

Even a snapshot of AI research highlights the facilitators of the era of AI we are living in, the AI future that is imperative, and the capabilities of AI:

- **Machine learning (ML)** and large-scale ML research, a subset of AI, looks into the design of learning algorithms with which the software can learn or adapt like a human can. Essentially, it analyzes huge amounts of data and looks for patterns to classify information or make predictions. The addition of a feedback loop allows the software to "learn" as it goes by modifying its approach based on whether the conclusions it draws are right or wrong and applying the newly discovered patterns to situations that were not covered by its initial design. With reinforcement learning, the focus of the machine learning is shifted from pattern recognition to experience-driven, sequential decision making. ML now powers everything from our spam filters to our Amazon shopping, telling us what to watch, what to buy, and whom to be friends with.
- **Deep learning (DL)** is also a subset of AI and another class of learning procedures. With DL, artificial neural networks identify patterns and can look at an image and recognize an object or a face of an individual. They can teach themselves how to, for example, play a video game without ever reading instructions.[7]
- **Collaborative systems** research looks into models and algorithms to help develop autonomous systems that can work collaboratively with other systems and humans.
- **Crowdsourcing and human computation**[8] research is a quest for methods to augment computer systems by using human expertise to solve problems that computers alone cannot solve. Human computation defines humans and computers working together to solve difficult problems that neither of them can solve alone[9], while crowdsourcing is the act of outsourcing tasks to a large and undefined group of people in the form of an open call[10, 11].
- **Automatic speech recognition** is one aspect of natural language processing. Current research looks into development of refined and capable systems that are able to interact with people through dialogue.
- **Computer vision** is a form of machine perception; computers are able to perform some vision tasks better than humans[12].
- **Robotics** is concerned with how to train a robot to interact with objects and people, the world around it. Advances in computer vision, as well as other forms of machine perception have been enhancing robotics.
- **Cyborg** research is on human and machine together becoming an integrated system, part human, part machine.
- With the **Internet of Things (IoT)** research, a wide array of devices, including appliances, vehicles, buildings, and cameras, can be interconnected to collect and share their sensory information to use for intelligent purposes.[13]
- **Neuromorphic computing** research emulates the neural structure of the human brain to improve the hardware efficiency and robustness of computing systems, often replacing separate modules for input/output, instruction-processing, and memory.
- **Brain-computer interface (BCI)** research looks into the ability of the human brain to generate certain types of responses that can then be harnessed by computers to be interpreted by computers.
- With **algorithmic game theory** and **computational social choice**, research is focused on how systems can handle incentives, including potentially misaligned incentives such as self-interested human participants or businesses and the automated AI-based agents representing them.

Clearly, a union of wide topics of research and advancements are leading AI developments, and we can see prospects for education and higher education.

To summarize the most important drivers of artificial intelligence: Computer power is growing, and this processing power enriches the capabilities of machines beyond imagination. The power of computers' connectivity, sensors, GPS systems, and gyroscopes also continues to grow. Algorithms and AI models are improving and becoming more sophisticated. Volumes of data fueling AI are being generated. Big data's potential keeps growing, and computers now learn from data, through machine learning, instead of by explicit programming. We are living the age of analytics and are competing in a big data-driven world. The range of opportunities and applications has grown big and will continue to grow bigger.[14] This confluence of data, better computing power, and better algorithms happened very fast and is powering at an extraordinary rate. Ethical concerns have been consequential, starting with who owns data, particularly data on individuals who can see it; who can use it; and for what purpose.[15]

While the AI world is evolving at an unprecedented rate, Japan at the moment sees it not fast enough. China considers implementations as more important than innovations[16], while the United States produces the most innovations.[17] Common to all of these leading countries is the wide discussion of the risks and the rewards of the AI world, continued extensive research in the field, and AI implementation at a record rate.

With more and more useful applications of AI that deliver important benefits with potentially positive impacts on society and economy, increases in the use of AI applications can be expected not only in the leading countries but worldwide. Education for all, healthcare diagnostics, targeted treatment, physical assistance for elder care, self-driving cars, legal assistance, and financial assistance are among these AI applications. Powered by AI, driverless cars are hitting the road, so are trucks in mines and vehicles in farm fields. Robots can climb stairs, open doors, win Jeopardy, play soccer, work in factories safely alongside humans, find parking spaces, and make restaurant reservations.

Robots can also analyze stocks and data, advise oncologists, be used to operate, interpret medical images, do legal research, act as teaching assistants, and debate with humans. These are all high-skilled functions that are now within the skill sets of machines.[18] With its capabilities, AI proves its worth for remarkable useful opportunities for humanity, giving us the power to, for example, tailor education to individual students, reach out to students anywhere in the world, improve medical diagnostics, advance legal systems, manage energy, and govern transport.

Though we shall discuss further, a few examples of existing AI influences are in order, as they shed light on expected further change in our lives. In particular, AI offers new possibilities for education/higher education, including future directions for research, enhancing jobs skills of graduates, and possible curriculum changes.

Having watched IBM's computer Watson[19] beat the human champions of the TV game show Jeopardy, a doctor approached IBM, and Watson was reborn as an oncology adviser. Computer scientists at IBM embedded Watson with all information from the Memorial Sloan Kettering Hospital's clinical trials; they then used advanced data analytics to train Watson to respond oncologists' questions. Watson is now helping oncologists make a data-driven and faster diagnosis and move toward a treatment plan quickly. Based on algorithms suitable to fulfill repetitive and relatively predictable tasks, Watson is used for student advising at Deakin University, in Australia, and a computer named Jill Watson, inspired by Watson, is used as a teaching assistant at Georgia Institute of Technology.[20]

In June 2018 IBM released the Robot Debater with the goal to help people build persuasive arguments and make well-informed decisions. Project Debater can debate humans on complex topics.

Robotic surgery or robot-assisted surgery is another example of AI in healthcare: it allows a surgeon's hand movements to be translated into smaller, more precise movements, using tiny instruments inside a patient's body. Controlled robotic arms are positioned above the patient and equipped with instruments or 3D cameras. A robotic arm operates when the surgeon on a separate console controls the arm while looking through a stereoscopic monitor. The monitor provides a high definition 3D view of the area operated on, resulting in a hyper-precise movement without human errors such as shaking of hands.

Big data's potential is also inherent in law. For example, Blue J LEGAL, a law firm in Canada, has been building legal software using AI and ML to predict legal outcomes. The software does much of the research for the lawyer. The lawyer tells the computer his/her problem and then the computer analyzes often a huge amount of cases to produce a personalized solution within seconds. It is a tailored explanation from its database that is sensitive to the facts that the lawyer has entered the system. Of course, the results are as good as the database.

Another use of AI is in an all-autonomous mine field in Australia with the tracks, conveyors, re-claimers, drills, and trains being autonomous. People take roles only in control rooms with huge computer screens to track operations in the field and trouble shoot if needed with a mouse or a video game controller from their computer desks.

And, as I was composing this paper, Alexa, as a listening assistant, played soft jazz music, and roborock vacuumed my living room at home with a set schedule instructed from my iPhone while I was at work.

Things that are harder for the machine to do are exhibit creativity, emotional intelligence, social skills, and perceptiveness. To give examples: Any creative-looking behavior of machines, such as when they make a smart move in the game of GO, Chess, Blitz[21], or Robo-Cup[22], is due to moves born out of exhaustive enumeration and evaluation of the underlying data, not actual creativity. Coaching/mentoring requires specific skills such as emotional intelligence, creativity, and communication; these are beyond machines' current capabilities. With assessing work, we can again automate some routine aspects of the work, but the work requires also specific skills, such as emotional intelligence, creativity, and communication.

Over the years, AI has developed to solve problems of increasing complexity. With the speed AI research and experimentations have been progressing, AI use has grown for a wide range of purposes. There has, however, been a gap between the capabilities of these algorithms and the usability of the AI systems by humans; consequently, one current concern is the development of human-aware intelligent systems[23] augmenting human capabilities across all fields[24]. Another concern is ethical and social issues raised by AI, including privacy concerns.

With regards to ethical and social issues, we realize differences in values of countries — China, for example, is more relaxed about privacy than western countries. Mega-corporations like Facebook, Google, and Amazon have also been very relaxed about the privacy of people.

Universities and colleges on the other hand, have long been fostering educated minds and responsible citizens attached to general values of humanism[25,26,27]. With education being the key to citizenship, higher-education institutions have been defined as building a student community, driving research and innovation, teaching and learning, creating collaborative learning experiences, and preparing students for future work with labor market relevance[28]. Also, lifelong learning, community contributions, and economic impact of higher education on national economies have been among significant roles of higher -education institutions. Universities and colleges have been analyzing and articulating contemporary forces that are causing industries and societies alike change, in order to foresee what impact of those changes will be on the university or college five or ten years in the future.

In exploration of the future of education and higher education in the era of AI, we need deploy AI-based technologies[29] in ways that enhance human capabilities. We will continue to promote useful AI technology and democratic values such as freedom, equality, and transparency[30, 31] and avoid being instrumental in creation of "Black Box Societies" [32, 33] whereby decisions are no longer based on human reflections but made automatically. It is vital to arouse awareness for such drawbacks of AI.

AI has been used and can be utilized further to consider alternative educational methodologies, improve the effectiveness of current methodologies, adopt novel ways of teaching and learning, enrich administration, reduce costs, and prepare graduates for the AI world of work. AI developments and implementations can enrich and accelerate the learning process and streamline a wide range of work of a university or college, including administrative tasks, the grading of course work, teaching and learning, research and innovation, campus life, lifelong learning, and skills development.

The impact of AI solutions relating to automated tasks, especially repetitive and relatively predictable tasks, on university administrative processes is obvious as is illustrated with the example of Watson at Australia's Deakin University. Jill Watson's use at the Georgia Institute of Technology as a teaching assistant is also an automated solution, in support of teaching and learning. With AI, machines can answer routine questions, grade homework, evaluate essays, and measure student responses. After all, the grading process of multiple-choice and fill-in-the-blank tests are often already automated. Machines can assist human grading for written response work as well. These capabilities of AI reflect in universities and colleges as time savers for professors to focus more on lesson planning, technology-enhanced lecturing, and one-on-one time with students for mentoring, coaching, and skills development.

In such an environment, universities and colleges avoid reducing educational processes to a set of automatic procedures for answering academic questions, content delivery, control, and assessment. They are freed up to stay true to building educated minds and responsible citizens attached to general values of humanism, including inquiry, creativity, innovation, and advancement of knowledge.

How AI Can Be Used as a Tool in Teaching and Learning

We have discussed for decades how to revolutionize education with technology.[34] 'Gamifying' instructional materials or expanding access to knowledge via massive open online courses (MOOCs) have been two prominent means. Blended, or hybrid, learning, with which students learn via electronic and online media as well as traditional face-to-face teaching, has been with us for some time now. The number of online classes has exploded in recent years: The Online Learning Consortium's 2016 survey revealed that 28 percent of American students surveyed took at least one online class. The rate has been increasing, with many students attending university or college strictly online and others taking courses on MOOC platforms such as Coursera and EdX. The Coursera Learner Outcomes Survey of 2019 shows that 87 percent of people learning for professional development through the MOOC achieve career benefits such as promotion, a raise, or starting a new career. AI can complement human teaching, making many models of learning scalable and repeatable.

Technology continues to develop rapidly, its adoption is widening, and AI presents significant opportunities to raise the quality of education to a level that our standardized curriculum and testing systems have not been able to achieve. AI can process far more information than a human can and perform tasks faster. Consider, for example, curriculum software developments; these capabilities of AI have been used to create programs that can adapt to each student's unique circumstances.[35] Adaptive learning solutions[36], for instance, personalize lesson plans to an individual student's existing knowledge, learning preferences, and progress in order to deliver the right content, at the right time and in the best way, to the student.

This approach avoids delivering one lesson to a class (one-size-fits-all model of learning) which can leave behind struggling students or disengage fast learners[37]. For the last few decades, many efforts have been made to tailor learning to each student with advances in what we can instead call a one-size-fits-one model of learning: Interactive, or virtual, tutors and robot teaching assistants are enabling personalized learning in an effort to optimize teaching and learning. Machine learning helps us personalize the students' learning, so that they can learn at a more efficient pace than they can in one-size-fits-all classrooms. New technologies including Personalized Learning Systems (PLS) and Intelligent Tutoring Systems (ITS) which learn how people learn and automate and accelerate grading, are among the facilitators of this customized learning through AI. [38,]

Massachusetts Institute of Technology's Digital Learning Strategies and Solutions[39] states the following: "Today's learners need a journey from concept to practice that includes accessible, bite-sized, and contextualized experiences in varying formats. Digital learning delivers on that promise by integrating across all learning areas and domains, and offering a learning journey that's scalable, accessible and malleable. … Digital learning creates an omnipresent learning experience."

With Natural Language, Computer Vision, and Deep Learning, machines can answer students' routine questions or act as tutorial supervisors. Through AI, tutoring and study programs are growing more advanced, capable of teaching fundamentals to students. Carnegie Learning, for example, is an intelligent tutoring system that uses data to provide feedback, and work with students directly. Inspired by IBM's Watson, an AI system designed to answer questions, the year 2014 saw a Georgia Tech professor and his research team create a robot teaching assistant, a chatbot called Jill Watson. Jill Watson answered the questions of students online throughout the whole semester.

To avoid any chaos, the questions were answered only when the system was 97 percent or more confident in its answers. Considering the thousands of questions that the professor and his teaching assistants typically receive each semester on the course's online form, many of which are repetitive questions, Jill Watson proved quite a help for them. When told at the end of the semester, students of the class remarked: "Just when I wanted to nominate Jill Watson as an outstanding TA", or "I feel like I am part of history because of Jill and the class".

Higher-education institutions are exploring AI applications that can help us learn how people learn: AI can identify indicators of successful learning for each student[40] by monitoring variables such as the number of times a student pauses during a lesson, the amount of time needed to answer a question, and the number of times a question is attempted before getting it right. Learning how people learn helps improve adaptive learning and personalized teaching. Computer Vision and Deep Learning can add further insights on each student's performance, confidence, mindset, and cognitive ability by eye tracking and sentiment analysis. These are important for retention and graduation rates in higher-education institutions.

There are tools that use ML to recommend engagement strategies to optimize retention and graduation rates by identifying students in trouble and offering them support before they drop out. Computer Vision is used to identify signs of students' disengagement by monitoring them as they work, tracking their eye movements and observing their expressions to check whether they are engaged, confused, or bored[41]. Computer Vision, Natural Language, and Deep Learning are experimented with, for example, in some schools in the UK and the U.S. to better understand the students' learning difficulties and learning preferences. Machine Learning can help us get a better sense of exactly where they are struggling or where the material has not been explained well, or a mix of

the two. Opportunities are bountiful: A virtual supervisor can use AI to track students' work and behavior and support instructors by supplying statistically based insights on students' progress and constructive feedback.

Along with transforming the learning experience and making learning available at the time of need, digital learning captures data[42], we can analyze for insights into student admission, retention, and success, the learning habits of individuals, and critical business decisions, ultimately increasing graduate fulfillment, employee satisfaction and job performance, and meeting the needs of the AI job market.

AI solutions may leverage voice and facial recognition to supervise an entire classroom and call out students individually. AI can enable instructors to establish the most effective groups or classes by applying ML to data from students' education profile and surveys.[43] ML can identify complementary skills that will maximize critical thinking and test students' capacity to adapt and collaborate.

Tangible change is happening in teaching and learning. What and how we teach is changing: Collaborative-, immersive-, and interactive learning environments are significant in today's education. Videoconferencing and 3D environments make learning through video an interactive and dynamic experience; i.e., much more than streamed lectures or recorded expert presentations and interviews. Video walls and digital signage also serve for the purpose. Interactive, multi-touch video walls and displays, wireless content sharing for mobile devices, and video conferencing are among the means for less emphasis on lecture model of learning and more on a collaborative and interactive model of learning. These are opportunities that inspire students in ways textbooks and static content cannot. Immersive virtualization labs have considerable impact on student learning, enabling them solve problems, make discoveries, and learn techniques through interactive data modeling.

Today's advanced technology allows for hologram-environments[44] where even the floor is a simulated environment. These 3D-environments allow user interaction via motion tracking, with images seamlessly warped and blended on any object and unprecedented image reliability using high resolution. Technology offers opportunities to simulate a physical presence in the real world or in an imagined world (Virtual Reality, or VR), overlay content in the real world (Augmented Reality, or AR), and merge the real and virtual worlds to produce new environments and visualizations where physical and digital objects co-exist and interact in real time (Mixed Reality, or MR). VR, AR, and MR have potential applications in education in providing new ways of learning. They are set to transform the content and delivery of education in class or online. Examples include Microsoft's Medical-holodeck for medical education. MR and gaming environments can be leveraged for learning purposes as in Pokémon Go.

Technologies used may vary from discipline to discipline, but they all lead to enriched teaching and learning experiences, improved career opportunities, and a skilled workforce. In the case of medicine, for example, there is the use of videoconferencing, medical simulation laboratories, and advanced visualization labs with 3D imaging. A student of medicine can walk into a lab, assess and treat a traumatic injury on a simulated patient, and then be evaluated by a physician at a remote location. This learning experience brings students hands-on simulation opportunity and visualization of their work in 3D, as well as collaboration with their professors and experts in the field.

To give an example on how AI serves as a tool for mass teaching and learning, UNESCO[45], estimates reveal the following data: Global need will be to recruit and train 24.4 million primary school teachers to achieve universal primary education by 2030 and 44.4 million secondary school teachers to fill openings at schools. A considerable portion of these new hires will replace those who leave education. AI could be part of the solution. With a much wider reach, AI-assisted teaching could have a significant impact in say, remote locations and third-world countries by supporting two key enablers of teaching: coaching and assessing.

Coaching and assessing require specific skills such as emotional intelligence, creativity, and communication that are beyond machines' current capabilities. Yet, with new indicators such as facial expressions, digital interactions, group interactions, and attention tracking, deep learning algorithms[46], could recognize patterns, sense attitudes towards learning situation, and track affective states, which could support students in real time. Indeed, an EU project iTalk2Learn[47], has been an open-source intelligent tutoring platform since 2015 to help primary school students, ages 5-11, learn mathematics. Using a combination of ML, user modeling, and natural language processing, the tool is able to interact with and respond to student's speech throughout a tutoring session.

How we teach and learn has kept pace with technological developments. However, we realize that today's and the future digital societies require students develop higher order intellectual skills for students to become digitally educated in all fields of study and shine in the AI world of work.

How AI Can Be Used as a Tool in Knowledge Management and Skills Development

There is the need for different educational outcomes in the age of AI that focus on the requirements and necessities of a digital society of today and tomorrow and its demand for high-level intellectual skills for graduates.

Content and skills are both crucial: Content and search for knowledge today can easily be delivered online. Skills on the other hand, (such as cognitive, inter- and intra-personal, and AI skills), call for special attention in this day and age, especially because of the changing nature of work in the era of AI. Creativity, problem solving, critical thinking, leadership, communication, collaboration, information management, adaptability, curiosity, and reflection are among the most significant skills.

Communication is beyond face-to-face in the digital age. Collaboration is with groups that are physical and virtual. And in an age where several quintillion bytes of data are created online every single day, information management skill is essential to narrow down the information and make it useful.

Professors today need shift emphasis from content delivery to identifying and developing core intellectual skills in students. They need to focus on teaching methods that support skills development, while academic departments need to focus on curriculum changes and learning outcomes to increasingly improve essential skills over the course of a program. Leaders of higher-education institutions and policymakers are to support this change fully.

Research on what skills to teach students and the expertise in skills teaching has been extensive. A shift to instructors explicitly working with students to teach these skills, however, has not yet received the attention and time it deserves. AI can change that as personalized technology-enhanced learning is here with us to better use the time at hand.

Graduates now are entering industries where the fundamentals of these jobs are changing. Realizing the times of unpredictable change, adaptability and resourcefulness are considered the heart and the sole of learning. The reflection of this in education is a more versatile education whereby the learning is both broad and deep, and the skills and character qualities achieved lead to compliance, creativity, and innovation to adapt to changing work environments. T-shaped teaching — learning pointing to the cognitive profile of someone whose knowledge is both deep and broad — and M-shaped teaching — learning associated with people who develop several depths over time — are philosophies of today adopted for versatility and resourcefulness.

Flagship Universities and World Class universities have been very good at giving people skills. 21st Century Universities and Colleges aim to help students achieve deep knowledge in their subject, woven together with skills they need to adaptively apply to that knowledge to overcome challenges in their careers in the AI world.[48] These are interpersonal skills (e.g., communications, teamwork, and leadership), intrapersonal skills (e.g., adaptability, initiative, discipline, ethics, persistence, and the ability to reflect on your process of learning to help you learn more effectively), cognitive skills and abilities (e.g., problem solving, critical thinking, and creativity), and technological skills (stand-alone as well as for enrichment of the first three skills and abilities). Employers today consider all four skills to be distinguishing and inseparable features for long-term success.

Educational experiences must be designed to account explicitly for all four of the skills. AI skills are indispensable in this day and age. Cognitive competencies are necessary, but they are not sufficient positive psychological capital. Emotional and social competencies, fostered by nurturing intra- and interpersonal skills, are essential to address the combination of hope, resilience, optimism, and efficacy needed by today's graduates. In STEM (Science, Technology, Engineering, and Mathematics) education, for example, the importance of cognitive skills is widely recognized, while humanist's grace in an AI world lies in liberal-arts education.

Education has always been about transfer (the process of making use of knowledge outside of the context in which it was learned), and expertise (a highly developed understanding of some domain of knowledge, including particular ways of perceiving and interpreting information). Data, information, knowledge, and understanding lead to expertise and transfer. With AI, the students of today can benefit from a curriculum that allows them to spend more time on transfer and expertise via concepts rather than on learning content that can now be easily accessed and is personalized. This is the flipped classroom.[49] With the flipped-classroom pedagogy of hybrid and blended learning, technology is used for learning content and carrying out research, often online, outside the classroom; class time, on the other hand, is used for activity-based concept learning and skills development with the guidance of a mentor.

As exemplified in this paper before, technology being created is important in an extensive range of work so that diversity in deep knowledge is vital. There is, for example, a global shortage of skilled people in STEM jobs. Also, curriculum changes are necessary. AI and advanced technologies need be integrated into the curricula of all disciplines and supported by effective strategic plans and educational goals.[50] Learning outcomes should comply with the requirements of the AI world of work. AI can play a key role in

better connecting education systems and labor markets to better meet the needs of future employers. Through the use of AI, higher-education institutions and governments can forecast job-market demand more accurately. Higher-education institutions can then adapt their curricula and approaches accordingly, making sure the graduates have the skills required to fill the jobs. [51]

Among the questions addressed by higher-education policy makers and institutions are:

- What skills are relevant to the labor market in light of the AI developments and deployments?
- How well does higher education generate skills that meet the labor market needs?
- What can policy makers do to help higher-education systems meet labor market needs?

Many institutions, including University of California Berkeley and Carnegie Mellon University, have been making disciplinary boundaries permeable and have launched cross-disciplinary programs such as science and mathematics education, science and technology studies, industrial engineering and operations research, behavioral economics, computational biology, and design, arts, and technology. National University of Singapore is a huge name in artificial intelligence and big data analytics.

At the Georgia Institute of Technology, scientific and engineering computing, technology and business, and music technology are among the programs that equip students with AI skills in their majors. A robotics minor is a concentrated experience in the multidisciplinary field of robotics that the Schools of Aerospace Engineering, Biomedical Engineering, Electrical and Computer Engineering, Interactive Computing, and Mechanical Engineering provide.

I would like to draw attention to Singapore University of Technology and Design's (SUTD) exemplary programs in how AI skills are given to graduates and how they prepare graduates for the AI world of work:

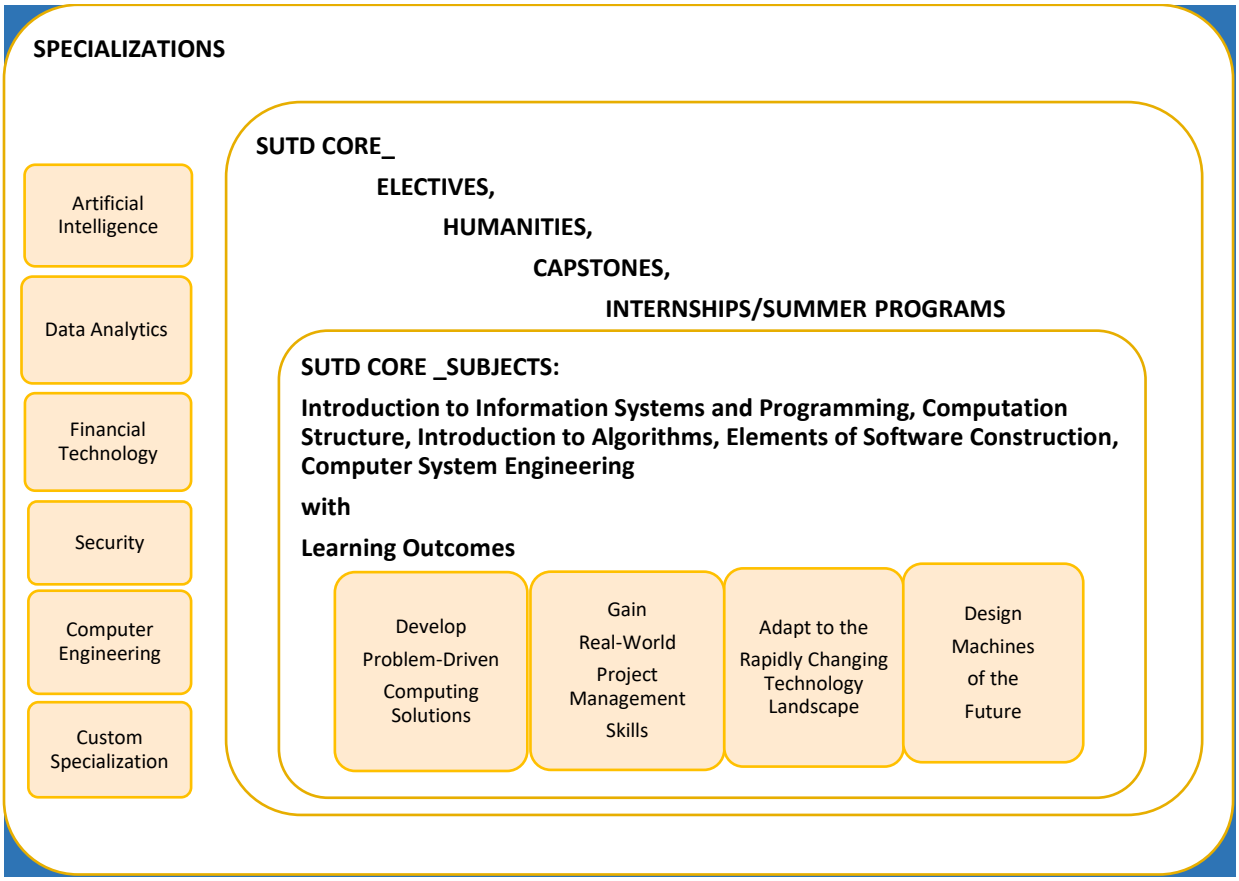
- Architecture and Sustainable Design prepares students for the present and future needs of architecture in a digital era;
- Design and Artificial Intelligence focuses on the application of AI-driven design across products, systems, services; and the built environment;
- Engineering and Product Development addresses the conception, design, implementation and operation of innovative technology-intensive products, with emphasis on products and systems whose development cuts across traditional disciplinary boundaries;
- Engineering Systems and Design focuses on the design, analysis, and management of large-scale complex systems such as financial services, supply chain and logistics, healthcare delivery, and transportation and aviation;
- Information Systems Technology and Design integrates the traditional disciplines of computer science, computer engineering, and information systems, focusing on the design of systems that interact with both humans and machines;
- Science and Mathematics engages students with hands-on learning experience to build a strong foundation in science and mathematics, research in the broader areas of science and mathematics that cut across disciplines, and a new pedagogy to enhance learning.

Humanities, Arts, and Social Sciences (HASS) complements the technical subjects to provide students with a grounding in the practice of inquiry, analysis, interpretation, and presentation. Among extensive research at SUTD, there is research on Articulated Systems and Biomechanics; and Bioinspired Robotics and Design. There are capstone projects[52] to prepare students to AI future.

Looking at the Information Systems Technology and Design (ISTD) program in more detail[53], we see an academic program with a strong focus on ISTD core subjects (computing, systems, and intelligence,) starting from term 4, enriched with courses in the humanities, arts, and social sciences. Electives are taken throughout terms 3-8, and capstone projects are worked on throughout terms 7-8.

There are also internships and summer programs in between the third and fourth and fifth and sixth terms. The first three terms focus on subjects including ISTD courses such as Modelling and Analysis, Computational Thinking for Design, Science for a Sustainable World, Design Thinking and Innovation, and Modelling Uncertainty; HASS courses like World Texts & Interpretations, and Theorizing Society, Self, & Culture; and any two electives, including Science for Healthcare and Data Driven World.

Expected learning outcomes of ISTD core are developing problem-driven computing solutions with a strong mathematical grounding, algorithmic thinking, and intense design; designing machines of the future by developing machines with augmented intelligence to solve complex problems; adapting to the rapidly changing technology landscape through mastering new computation technologies that constantly emerge through hands-on projects; and gaining real-world project management skills through building products, systems, and services through multi-disciplinary projects.



Of course, academic programs evolve with time following the needs of the society and requirements of the changing world of work. Today's ISTD program offers specializations in Data Analytics, Artificial Intelligence, Custom Specialization, Financial Technology, Security, and Computer Engineering.

ISTD offers also minors for more choices and flexibility in pursuing one's broader interests and achieving additional knowledge. Minors include artificial intelligence, healthcare informatics, digital humanities, and design, technology, and society (DTS).

ISTD graduates are prepared for a wide range of computing and management careers. ISTD graduates' current job titles include IT security specialist, data analyst and scientist, software and multimedia developer, systems analyst and engineer, industrial engineer, business and management consultant, financial analyst, infrastructure engineer and architect, software or project manager.

Thus, AI is taken to heart at SUTD. This reflects fully in the undergraduate programs, graduate programs, and research to give the graduates high-level competencies in skills and their subject matters and opportunities for research and to prepare them for an AI world of work. ISTD, quite rightly, is proud about giving graduates future-ready career skills, equipping them with specializations, a problem-oriented approach, and a holistic understanding of the world.

Jobs and Workforce in an AI World

AI continues to develop, and the world needs talent more than ever before. Automation and artificial intelligence are changing the nature of the work. Some tasks are being done by robots or offshored, or robots are working alongside humans. New professions are appearing for humans while some are disappearing. Consequently, there are shifts in workforce skills and how work is organized.[54] Too many recent graduates have been trained for jobs that may change, or go away, rather than equipped with skills that will be ever more valuable for changing jobs or for new jobs that we cannot yet envisage. Universities and colleges are therefore to provide the workforce with foundational competencies and skills they need for now — and into the future. While automation and the concerns about the effects it will have on jobs have led to tremendous anxiety about workforce issues in an AI future, identifying which skills are most uniquely human and encouraging students to commit to lifelong learning to stay relevant alongside robot coworkers appears most important.

An October 2019 report of OECD, the Organization for Economic Co-operation and Development, reveals that about 14 percent of jobs across its member countries are highly automatable and another 32 percent will be radically transformed by AI advances. An October 2016 Report of MGI McKinsey Global Institute shows that 20 to 30 percent of the working-age population in the United States and the EU is engaged in technology-enabled and on-demand, independent work, and this number is expected to grow.

A December 2017 Report of MGI[55] studied 46 countries representing almost 90 percent of global GDP and points out that about 30 percent of hours worked globally could be automated by 2030, depending on the speed of adoption. The report also gives a detailed study of six countries (China, Germany, India, Japan, Mexico, and the U.S.) to illustrate the potential impact of automation on future labor demand and economies. In the U.S., for example, up to one-third of the workforce may need to change occupational categories.

Research on AI and its impact on work and economies continues. Further publications will add to what we already know through the above-mentioned reports alike and research. The 21st Century Universities and Colleges will meet the educational objectives to not only get that first job after graduation, but to also achieve career changes and advancements over time, filling the skills gap and providing retraining for a shift in career.

Discussion and Conclusion

Within the limits of a paper, we have talked about how AI world is evolving, how AI can be used as a tool in teaching and learning, knowledge management and skills development; AI as a skill that higher-education institutions need to teach along with human skills; possible curriculum changes; and jobs and workforce in an AI world. To remain relevant, the 21st Century Universities and Colleges must evolve and adapt the age of AI.

As this paper demonstrates, big data, information, and computing power play the dominant role in the AI world. Intelligent automation collaborating effectively with humans is an opportunity for humans to use AI as a tool for enhancing what humans do.

While the growing importance of AI in the workplace will doubtless affect what universities and colleges teach, it also has an impact on how they teach and on how students learn. Automation and the gig economy are radically changing job descriptions and how we work, making human and AI skills, adaptability, and resourcefulness key to success. Learning today needs to be cross-disciplinary, personalized, and focused on skills.[56] It is important that students become confident about how the technology is applied within their subject area(s) and commit to lifelong learning to stay relevant alongside robot coworkers.

AI raises substantial ethical and social issues for humans to take precautions accordingly. A core principle of higher education is to foster freedom of thinking and inquiry, academic skepticism, in-depth understanding and the advancement of knowledge. As noted in Thomas Arnold's *Academic Freedom: A "Special Concern of the First Amendment"*[57], "No [one] ought to meddle with the universities, who does not know them well and love them well."[58]

ENDNOTES

1 Artificial Intelligence the Next Digital Frontier? McKinsey Global Institute MGI; Discussion Paper, June 2017; AI is a broad term used to describe any technology that mimics human intelligence. AI solutions go back to 1950 with the British Mathematician and Logician Alan Turing, Founding Father of AI) who described a system designed by a human as intelligent if the distinction of a conversation with the system or another human cannot be made: https://www.britannica.com/print/article/609739; American Computer Scientist John McCarthy (Father of AI) defined AI in 1956 with the premise that every aspect of learning or any other feature of human intelligence can in principle be so precisely described that a machine can be made to simulate it: https://www.independent.co.uk/news/obituaries/john-mccarthy-computer-scientist-known-as-the-father-of-ai-6255307; Since then AI solutions have been developing extensively; Russel Stuart J & Norvig Peter, "Artificial Intelligence: A Modern Approach," (3rd Ed., 2010): http://aima.cs.berkeley.edu/; See IBM Supercomputer beats humans in Jeopardy, 2011: https://www.youtube.com/watch?v=WFR3lOm_xhE; Gibney Elizabeth, "Google secretly tested AI bot - Updated version of Google DeepMind's AlphaGo program revealed as mystery online player," Nature, Vol 541, 4 January 2017: https://www.nature.com/news/google-reveals-secret-test-of-ai-bot-to-beat-top-go-players-1.21253.

2 Joseph E. Aoun, Robot-Proof: Higher Education in the Age of Artificial Intelligence, MIT Press, 2017.

3 Asilomar Study on Long-Term AI Futures: Highlights of 2008-2009 AAAI Study: Presidential Panel on Long-Term AI Futures, http://www.aaai.org/Organization/presidential-panel.php

[4] Campus Technology "The Future Ready University", Nov. 2019; The Transformation-Ready Higher Education Institution_ How Leaders Can Prepare for and Promote Change", HURON, The American Council on Education (ACE) and the Georgia Institute of Technology, Oct 22, 2019

[5] See "The Risks and Rewards of AI", Harvard Business Review, February 2018; Farnam Jahanian, "How higher education can adapt to the future of work," World Economic Forum, 21 Jan 2020: https://www.weform.org/agenda/2020/01/how-can-higher-education-adapt-to-a-constantly-evolving-future-of-work/

[6] See 40 best colleges in the US for AI https://www.greatvaluecolleges.net/artificial-intelligence-colleges/; Hunter Gehlbach and Lindsay Page, "The Risks and Rewards of AI," Harvard Business Review, February 2018.

[7] Elizabeth Lopatto, "Google's AI Can Learn to Play Video Games" The Verge, February 25, 2015: http://www.theverge.com/2015/2/25/8108399/google-ai-deepmind-video-games

[8] Thimo Schulze, Dennis Nordheimer and Martin Schader, "Worker Perception of Quality Assurance Mechanisms in Crowdsourcing and Human Computation Markets", University of Mannheim Business School Germany: Proceedings of the Nineteenth Americas Conference on Information Systems, Chicago, Illinois, August 15-17, 2013.

[9] Quinn A.J. and Bederson B.B, "Human Computation: A Survey and Taxonomy of a Growing Field," University of Maryland, College Park: http://wwww.alexquinn.org/papers/Human%20Computation,%20A%20Survey%20and%20Taxonomy%20of%20a%20Growing%20Field%20(CHI%202011).pdf; CHI 2011 Conference (The ACM CHI International Conference on Human Factors in Computing Systems, May 7-21, 2011, Vancouver, BC, Canada, 2011.

[10] Howe J., "Crowdsourcing: Why the Power of the Crowd is Driving the Future of Business", Crown Publishing Group, 2008.

[11] Wikipedia's collaborative knowledge creation is an example of crowdsourcing.

[12] See e.g. Andrew G. Howard, Menglong Zhu, Bo Chen, Dmitry Kalenichenko, Weijun Wang, Tobias Weyand, Marco Andreetto, Hartwig Adam "MobileNets: Efficient Convolutional Neural Networks for Mobile Vision Applications," Google Inc, Apr 2017: https://arxiv.org/abs/1704.04861

[13] Your mobile phone connects to your Robotic Vacuum Cleaner to start cleaning in your absence (see e.g. https://en.roborock.com/pages/roborock-s5).

[14] Greg Toppo, "Big Data: AI prompt major expansions at UC Berkeley and MIT," Inside Higher Education, Nov 2, 2018; https://www.insidehighered.com/print/news/2018/11/02/big-data-ai-prompt-major-expansions-uc-berkeley-and-mit; Jonathan S. Gagliardi, "The Analytics Revolution in Higher Education", in Jonathan S. Gagliardi, Amelia Parnell, Julia Carpenter-Hubin (ed), Big Data, Organizational Learning and Student Success, Stylus Publishing LLC, 2018; Campus Technology "New Data Literacy Institute Will Help Institutions Harness Data for Student Success", Rhea Kelly, 02/06/2020: https://campustechnology.com/articles/2020/02/06/new-data-literacy-institute-will-help-institutions-harness-data-for-student-success.aspx: The Association of Public and Land-Grant Universities (APLU) and Association for Institutional Research (AIR) are teaming up for a pilot that will provide data literacy training to APLU member campuses. The Data Literacy Institute, funded by a $670,000 grant from Ascendium Education Group, will offer coursework developed by AIR on the use of data to boost student success.

[15] Pasquale F. "The Black Box Society. The Secret Algorithms that Control Money and Information", Cambridge, Mass., Harvard University Press, 2015,; McKinsey and Company "Consumer-data privacy and personalization at scale: How leading retailers and consumer brands can strategize for both", Julien Boudet, Jess Huang, Kathryn Rathje, and Marc Sorel, Nov. 2019: https://www.mckinsey.com/business-functions/marketing-and-sales/our-insights/consumer-data-privacy-and-personalization-at-scale

[16] Martin Wolf, "China Battles the US in the Artificial Intelligence Arms Race: What counts is implementation not innovation, and here the Chinese have big advantages, Financial Times, April 16, 2019.

[17] Accelerating America's Leadership in Artificial Intelligence, Office of Science and Technology Policy, The White House, US, Feb 11, 2019 https://www.whitehouse.gov/articles/accelerating-americas-leadership-in-artificial-intelligence/; Kai-Fu Lee, AI Super-Powers_ China, Silicon Valley, and the New World Order, Houghton Mifflin Harcourt Boston, New York, 2018

[18] Joseph E. Aoun, Robot-Proof: Higher Education in the Age of Artificial Intelligence, MIT Press, 2017

[19] "Watson is a question-answering computer system capable of answering questions posed in natural language, developed in IBM's Deep QA project by a research team led by principal investigator David Ferrucci. Watson was named after IBM's first CEO, industrialist Thomas J. Watson.

[20] Georgia Institute of Technology has created and used a robot teaching assistant named Jill Watson: http://ted.com/tedx.

[21] Robot vs World Champion blitz game. First in the history! Nov 2010: https://www.youtube.com/watch?v=2fQpZCamuBs.

[22] "RoboCup 2019: Robots show off their skills on the pitch", Sydney Australia: https://www.youtube.com/watch?v=_Y5_iGxWFrQ.

[23] Thibault Kruse, Amit Kumar Pandey, Rachid Alami, and Alexandra Kirsch, "Human-aware robot navigation: A survey in Robotics and Autonomous Systems," Volume 61, Issue 12, , Pages 1726-1743, December 2013.

[24] See e.g., "The US National Artificial Intelligence R&D Strategic Plan (Obama's 2016, and Trump's 2019 Update)"

[25] Charles M.West, The American Research University from World War II to the World Wide Web, , UC Press, 2007.

[26] "Dynamics of the Contemporary University_ Growth, Accretion, and Conflict", Neil J. Smelser, UC Press, 2013.

[27] "The New Flagship University_ Changing the Paradigm from Global ranking to National relevancy", Ed. John Aubrey Douglass, Palgrave. MacMillan, 2015

[28] Higher Education in Norway: Labor Market Relevance and Outcomes, OECD 2018: "The HE system in Norway generally produces graduates with good skills and labor market outcomes. This success can be largely attributed to Norway's robust and inclusive labor market and recent HE reforms to improve quality. However, some Norwegian students have poor labor market outcomes…. This report provides advice and recommendations to improve the labor market relevance and outcomes of HE in Norway. The analysis finds that there is an opportunity to expand work-based learning opportunities, improve career guidance, and do a better job of using innovative learning and teaching practices to improve labor market relevance across system. The report concludes that Norwegian Policy Makers have a larger role to play in steering the system. ..." In a survey across 10 developed and developing countries, only half of students believed their post-secondary studies improved their employability, and more than a third of employers thought skills shortages are a leading reason for entry-level vacancies. Not only does the resulting skills gap lead to economic underperformance, it also means that many individuals are not given the opportunity to reach their full potential; National Research Council 2012. Education for Life and Work: Developing Transferable knowledge and Skills in the 21st Century, Washington DC. The National Academics Press.

[29] Dian Schaffhauser, "Campus Technology "Higher Ed Tech Investment Soar," 01/30/2020: https://campustechnology.com/articles/2020/01/30/higher-ed-tech-investments-soar.aspx.

[30] "Dian Schafhauser, AIR Publishes Ethical Principles for Use of Data in Higher Ed", Campus Technology Data Analytics , February 11, 2020: https://campustechnology.com/Articles/2020/02/11/AIR-Publishes.

[31] European Commission White Paper on "Artificial Intelligence- A European Approach to Excellence and Trust", Brussels, 9.2.2020, COM (2020) 65 final.

[32] Frank Pasquale, "The Black Box Society. The secret algorithms that control money and information". Cambridge, Mass. Harvard university Press, 2015.

[33] Joseph E. Aoun, "Robot-Proof _ Higher Education in the Age of Artificial Intelligence", The MIT Press, 2017

[34] 2015 estimates show that schools in the US spent nearly $160Billion on educational technology, and the spending is forecasted to grow 17% annually through 2020. Further, private investment in educational technology, broadly defined as the use of computers or other technology to enhance teaching, grew 32% annually from 2011 to 2015, rising to $4.5Billion globally; see also http://www.onlinelearningsurvey.com/reports/goingthedistance.pdf

[35] Alice Hathaway, "The Promise (and Pitfalls) of AI for Education", Dennis Pierce, Times Higher Education, August 29, 2018; Stefan Popenici, "Deceptive Promises – the Meaning of MOOCs-Hype for Higher Education," In Blended Learning: Concepts, Methodologies, Tools, and Applications , Vol. 4, pp. 691-701, 2016: https://doi.org/10.4018/978-1-5225-0783-3.ch034.

[36] Tyton Partners, "Learning to Adapt. 2.0: The evolution of adaptive learning in Higher Education". 2016

[37] Well over ten years ago at the Eastern Mediterranean University in Northern Cyprus, MathXL was used for undergraduate mathematics classes. MathXL has features for instructors and students; for students: Interactive tutorial exercises, eBook with multimedia learning aids, and Study plan for self-paced learning; for Instructors: Homework and test manager, Custom exercise builder, Comprehensive gradebook tracking, Complete online course content and customization tools, Copy or share courses, and manage course groups. These tools are designed to support teacher/instructor and tutor approaches to student difficulties and are expected to continue advance, addressing a range of learning styles with visual and dynamic learning channels:https://www.pearson.com/ca/en/higher-education/products-services-teaching/digital-learning-environments/mathxl.html.

[38] Cathy N. Davidson, "The New Education: How to revolutionize the university to prepare students for a World in flux" Basic Books, New York, 2017; Educational Leadership, Knowledge and Technology Innovation in Cultural Diversity and Knowledge-Based Society" Abstracts. OARIC 2011 International Conference, April 25-27, 2011, Phuket, Thailand: http://www.oaric2011.psu.ac.th.

[39] MIT Digital Learning Strategies & Solutions states, "Singular learning instances are outdated. Today's learners need a journey from concept to practice that includes accessible, bite-sized, and contextualized experiences in varying formats. Digital learning delivers on that promise by integrating across all learning areas and domains and offering a learning journey that's scalable, accessible, and malleable. It is ideal for workers who have adopted connected devices in their daily lives and expect a similar, high level of sophistication at work. The strength in digital learning lies in using enabling technologies and combining innovative strategies to create an omnipresent learning experience: https://www.gpstrategies.com/solution/digital-learning/?gclid=EAIaIQobChMIko_y3MiK3QIVWYmyCh2o8wjZEAAYAiAAEgJWZ_D_BwE.

[40] Arti Ramesh, Dan Goldwasser, Bert Huang, Hal Daume III, and Lise Getoor, "Modeling Learner Engagement in MOOCs using Probabilistic Soft Logic", Department of Computer Science, University of Maryland, MD, USA.

[41] See www.youtube.com How China is using AI in Classrooms| WJS Wall Street Journal: "A growing number of classrooms in China are equipped with artificial-intelligence cameras and brain-wave trackers. While many parents and teachers see them as tools to improve grades, they have become some children's worst nightmare"

[42] "A labor market that works: Connecting talent with opportunity in the Digital Age", McKinsey Global Institute, June 2015; see also "Education to Employment: Designing a System that Works", McKinsey & Company, 2013. "Labor market mismatch and labor productivity: Evidence from PIIAC data", Müge Adalet McGowan and Dan Andrews, OECD, April 28, 2015, An example of this is Saudi Arabia's current exploration of machine learning ML as a tool to reduce unemployment. The administration hopes to leverage large amounts of past and forecasted economic and social information about the country to possibly guide students toward an education best matched to their abilities.

[43] Startups such as Collaboration.ai use AI to process data on each student's experience, knowledge, and capabilities; to create instantaneous maps of connections and networks; to highlight each student's specific potential; to break down preferences and bias; and to recommend group formations best suited for the learning objective.

[44] Gary W. Frazer and George H. Stevens, "Holography: A Transformative Technology for Learning and Human Performance Improvement" Educational Technology, Vol. 55, No. 6, pp. 38-42, November-December 2015.

[45] Human Centered Artificial Intelligence_ The Role of UNESCO: https://www.youtube.com/watch?v=FDOptbuz_fg&index=3&list=PLWuYED1WVJIOH_a83AluOObuLqVZqvg53&t=0s

[46] Yangming Guo, Yu Liu, Ard Oerlemans, Songyang Lao, Song Wu, Michael S. Lew, Deep learning for visual understanding: A review, Elsevier, 2016 https://www.sciencedirect.com/science/article/abs/pii/S0925231215017634

[47] iTalk2Learn "Talk, Tutor, Explore, Learn: Intelligent Tutoring and Exploration for Robust Learning" was a collaborative European project (Nov.2012 – Oct.2015), an interdisciplinary project pooling expertise from machine learning, user modelling, intelligent tutoring systems, natural language processing, educational psychology and mathematics education. iTalk2Learn enables personalized learning at scale as it's an innovative, open-source learning platform for children learning mathematics, and intelligent tutoring platform that supports mathematics learning for students aged 5 to 11, delivering the right lesson at the right time for every child.

[48] John A. Douglass, The New Flagship University _ Changing the Paradigm from Global Ranking to National Relevancy, Palgrave Macmillan, 2016; Charles M. Vest, The American Research University: from World War II to World Wide Web, Governments, The Private Sector, and the Emerging Meta-University,UC Press 2007.

[49] Artificial Intelligence in Education: Promises and Implications for Teaching and Learning March 2019 Center for Curriculum Redesign; Four-Dimensional Education: The Competencies Learners Need to Succeed October 2015 Center for Curriculum Redesign

[50] The impact of AI on curriculum systems: towards an orbit-shifting dialogue, UNESCO, 2019: https://unesdoc.unesco.org/ark:/48223/pf0000371258

[51] The players in the field include employment oriented social network LinkedIn that acquired educational website.

[52] E.g. "Designed for a Better Future: Trailblazing Capstone Projects of 2019" https://wearesutd.sutd.edu.sg/sutd-ents/designed-for-a-better-future-trailblazing-capstone-projects-of-2019/

[53] Information Systems Technology and Design (ISTD), Singapore University of Technology and Design (SUTD): https://www.sutd.edu.sg/SUTD/media/SUTD/ISTD.pdf?ext=.pdf

[54] Mc Kinsey and Company, "Skill Shift: Automation and the Future of the Workforce", Jacques Bughin, Eric Hazan, Susan Lund, Peter Dahlström, Anna Wiesinger, and Amresh Subramaniam, May 2018: https://www.mckinsey.com/featured-insights/future-of-work/skill-shift-automation-and-the-future-of-the-workforce.

[55] Jobs Lost, Jobs Gained: Workforce Transitions in a time of Automation, McKinsey & Company, MGI, Dec.2017

[56] Hamdy Abdelaziz, "The impact of AI on curriculum systems: towards an orbit-shifting dialogue, UNESCO, 2019: https://unesdoc.unesco.org/ark:/48223/pf0000371258

[57] J. Peter Byrne, "Academic Freedom: A "Special Concern of the First Amendment," The Yale Law Journal, Volume 99, Number 2, November 1989

[58] Letter to George Pryme (Mar. 8, 1837), Reprinted in 2 A. Stanley, The Life And Correspondence Of Thomas Arnold, D.D. 67, 69 (12th Ed. 1881).