International Journal of Social Policy and Education
Vol. 2, No. 10; December, 2020. pp 31-39
ISSN 2689-4998 (print), 2689-5013 (online)

Published by International Center for Promoting Knowledge
www.icpknet.org

Analyzing Computer Courses in Electrical Engineering Programs of UAE Universities – Industry 4.0 Perspective

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Abstract

Industry 4.0 is a vision spelled out in high-tech strategy of the developed countries. The technologies envisioned to see industrial growth are based upon information and communication technologies to achieve higher production rates, flexibility in production, real-time fault diagnosis, and a lower wastage rate in production. Such high-end enabling technologies require relevant professional skills of graduates from academia. The task of governments of developed countries is to adapt the curriculum of engineering institutions to skills perceived as necessary to meet demands of industry 4.0 compliant industries. This work, first, discusses necessary components in engineering, in general, and electrical engineering in particular. A literature review is conducted to highlight current research, identify studies that are focused on engineering education especially electrical engineering. Later, industry 4.0 outlook in United Arab Emirates is investigated regarding industry 4.0 technological challenges. After that, electrical engineering curriculum in most of the well-known UAE universities is surveyed to identify depth and breadth of computer courses, and weakness are identified to build a two-way path to meet skills requirements of industry 4.0 technologies. Future directions are discussed.

Keywords: Electrical Engineering; Industry 4.0; UAE Universities; Technology in Education; Education 4.0

1. Introduction

In order to explore the direction and growth of industry and current curricula of electrical engineering program in various universities in United Arab Emirates, the scope of computer courses, in general, needs to be highlighted in terms of its evolution, its depth and breadth, current models and learning outcomes, emerging technologies, etc. Below, each of these components are highlighted briefly to provide relevance to the reader.

1.1 Evolution of the field

Initial curricular efforts in computer courses commonly known as a specialization within electrical engineering, extend digital logic design to the design of microprocessors and embedded systems. Later curricula increasingly began to include relevant knowledge areas from computer science. In China, the Ministry of Education specified 'computer science and technology' as the first-class discipline that included 'computer software and theory', 'computer systems organization', and 'cyberspace security' as new first-class disciplines (Greg, 2018). Within the UK, nowadays, degree courses in "computer systems engineering" or "computing and electronic systems" are far more common (Crick, 2017). In the United States, as of October 2015, the EAC of ABET has accredited over 279 computer engineering or similarly named programs. The evolution may take many forms, and this includes an expanded content or tighter integration with software engineering disciplines on application-focused projects and embedded systems with a greater emphasis on design and analysis tools to manage complexity. A re-integration with electrical engineering may also emerge in areas such as control systems and telecommunications.

1.2 Ability to design

Design is fundamental to the electrical engineering. From computing view in electrical engineering, the design relates to applying theories and principles of science and mathematics to design and integrate hardware, software, networks, and processes and to solve electrical problems as continuing advances in computers and digital systems have created opportunities for applying these developments to a broad range of applications in engineering.

1.3 Depth and Breadth of knowledge

One common measure for differentiating computer related courses in electrical engineering programs is the relative amount of emphasis placed on areas that are commonly associated with either electrical engineering or computer science programs. At one extreme, it could provide opportunities to study a wide range of subjects, while at another extreme, it might focus on one specific aspect of computer engineering and cover it in great depth. In all, the graduates should complete a sequence of design experiences, encompassing hardware and software elements and their integration, building on prior work, and including at least one major project.

1.4 Program evaluation and accreditation

Many countries have established their own processes for evaluation and/or accreditation through governmental or professional societies. In general, institutions tend to use accreditation as a vehicle to provide evidence of quality that they can use in marketing activities; most institutions offering electrical engineering degrees will have some form of recognition in accreditation terms. In all, the learning outcomes should emphasize achieving potential to be creative and innovative in their application of the principles covered in the curriculum to contribute significantly to the analysis, design, and development of complex systems. The curriculum models include various strategies that depend upon the environment:

1.4.1 *Strategies for Emerging Technologies*: The specialization specific fields of electrical engineering have changed drastically in recent times and there is an unwritten promise that the change in these areas will accelerate in the future. Hence, electrical engineering curricula should include concepts that enable students to adapt to new and emerging technologies in an agile manner. They should be able to identify emerging technologies and identify companies that have failed because they did not adapt to a changing field.

1.4.2 *Applied Emerging Technologies*: Electrical engineers should be aware of applied emerging technologies. The corresponding computing technologies already exist in the marketplace, but they are sufficiently new and their influence on society is not completely known. The curricula should enable students to identify some applied emerging technologies and indicate their effects on engineering. For example, teachers might encourage testing in ways in which 3D printers might produce artifacts that are harmful to society or describe the challenges one would face in designing and producing integrated circuits. As another example, students should be able to explain ways in which nanotechnology or the internet of things (IoT) can transform the technological workplace. Electrical engineers with computer courses are already interacting with optical, biological, or quantum computers or they will be designing a new-age robotic system for manufacturing.

1.4.3 *Conceptual Emerging Technologies*: Electrical engineers should also be aware of conceptual emerging technologies. These technologies are those that exist in some developing state with recent entrance or possible entrance in the marketplace. The computer course curricula should identify some conceptual emerging technologies and indicate some of their effects of on computer engineering.

1.4.4 *Laboratory experiences*: Laboratory experiences are an essential part of the computer courses in electrical engineering and they serve multiple functions. As in any engineering curriculum, it is important that computer courses should have many opportunities to observe, explore, and manipulate characteristics and behaviors of actual devices, systems, and processes. This includes designing, implementing, testing, and documenting hardware and software, designing experiments to acquire data, analyzing and interpreting that data, and using that data to correct or improve the design and to verify that it meets specifications. Intermediate and advanced laboratories should include problems that are more open-ended, requiring students to design and implement solutions or requiring them to design experiments to acquire data needed to complete the design or to measure various characteristics. Good lab experience forces students to demonstrate that they understand basic knowledge by successfully creating a program or hardware system to meet a set of criteria. It also exposes the student to state-of-the-art tools and methodologies that will prepare them for real engineering work after graduation.

1.5 Literature Review

In this millennium, as technology began to infiltrate the educational institutions, instructors started to use technology in ways, what we call Education 2.0. The emergence of Tablets and smartphone in the last decade, supportive classrooms, online classes and assessments, robotics, and Artificial Intelligence (AI), and big data have all penetrated in educational environment. As time passed by, Internet turned to be more user-driven, and thus Education 3.0 was developed. Now, students started access to learn virtually and connections to various platforms including faculty became prevalent. This created network-oriented approach for students having direct links with variety of information resources. These platforms and access to information word wide has created personalized way of learning, where students experience independence and explore unique way of learning. These changed has created Education 4.0.

To match industrial demand on engineering education, German Federal Ministry of Education and Research launched an education related research project (Grodotzki, et. Al, 201), where virtual representation of labs for different devices were developed to explore and investigate complex processes, and then embed these labs as part of lectures in different programs. In the second phase of this project, such labs are being broadened to include Augmented Reality and Additive Manufacturing technologies. Education 4.0 has been in focus of many educationalists and governments, but its current state in terms of assessments, sustainability, agility of governments, etc. is not in good state and needs improvements. This poor state has also been caused by lack of readiness of stakeholders in terms of relevant update in technology and skills. The authors (Chea, et. al., 2019) discuss outlook of Education 4.0 and related challenges. To analyze current outlook of Education 4.0 in response to Industry 4.0, the author (Hussain, 2018) discusses trends of Education 4.0 in its implementation like skills for teachers, classroom environment, student feedback, etc. In another work (Mourtzis, et al., 2018) the manufacturing education, also termed as teaching factory is investigated, where Education 4.0 in networked ecosystem of devices is addressed to build skills in this new era of cyber-physical systems and related technologies. To develop current curricula in line with industry 4.0 challenges and required competencies, the authors (Ellahi, et al., 2019) focus on developing a qualitative curriculum matrix to pace up to industry 4.0 challenges.

Though the industry 4.0 idea is not new and has been on the agenda of research communities with different perceptions, the Industry 4.0 initiative has recently gained a well-deserved attention, as stated earlier, and has been considered a well-accepted term in the industries as well. While academia focuses on refining the concept to develop systems, models and methodologies, the industry, on the other hand, concentrates on bringing change in industrial processes using intelligent suits and products with focus on potential customers (Oztemel and Gursev, 2018). In another work, the authors (Mogos, et. al., 218) after analyzing the main technologies of Education 4.0, highlight the role Industry 4.0 in shaping the engineering education itself for sustainability. The authors argue that Education 4.0 environment is based on education faculty, students, education administrators for improving the education practices. It improves education settings where different actors create combined value at different levels. The authors emphasize that such platform development requires government support in introducing intelligent educational infrastructure to pace up with Industry 4.0 requirements. In another research (da Motta Reis J.S. et al., 2020), the objective of the authors is to identify research gaps and suggest groupings through themes. The adopted method was based on a literature review conducted in this research and then became a basis for highlighting gaps found in relevant publications versus corresponding variations indexed in Scopus database. Using these gaps, the investigation was able to point out five groups that address similar characteristics regarding Education 4.0.

The race for the fourth industrial revolution (industry 4.0) is on. Each country (developed or developing) should participate and to this date, many countries have developed strategic programs to initiate industry 4.0 implementation. As stated earlier, though industry 4.0 has been of focus in academia, how many and to what extent each industry 4.0 launched initiative has met its goals, has never been divulged (Bongomin, et. al., 2020). The reasons are obvious since the expectations from Industry 4.0 vision are not limited to new approaches but also the methodologies and technologies, which needs to be introduced into companies. This transition is not possible easily, and the prime reasons being high financial costs and the lack of required employee qualifications (Benešová and Tupa, 2017). As far as Industry 4.0 implementation opportunities are concerned, exploiting these requires a targeted implementation. The authors in (Veile, et. al., 2019) discuss understanding of relevant implementation actions and recommend specific actions that need to be undertaken to speed up the realization.

This research addresses effort to analyze integration of computer courses in the electrical engineering so that students are enabled to handle professions in emerging world both in concept and applied sense. This research effort is organized as follow. In the next section, regional industry outlook is examined vis-à-vis industry 4.0 challenges, and related work in academia. Section three presents current curricula in UAE educational institutions and suggestions are developed to integrate industry 4.0 technologies in electrical engineering. In section 4, discussions and conclusions are presented, followed by references.

2. Regional Industry Evolution and Direction

The development of new business models, flexible production, and greater productivity are all possible today due to digital solutions. The innovative cutting-edge technologies create opportunities for discrete and process industries to meet market requirements, using Digital Enterprise solution portfolio. The Industry 4.0 is an ongoing transformation to integrate and digitalize business processes of manufacturing and industrial practices with latest smart technology.

In such an environment, devices, sensors, and people involved in production processes are increasingly connected, as manufacturing process is increasingly reliant on machine learning and smart technologies. This includes automation, operation, and system services to integrate with suppliers and logistics on a collaborative platform. Since the complexity in engineering industry increases at the same rate as the automation component proliferates, thus engineering must counter this development with flexibility, quality, and consistency.

A lot of work has been conducted to highlight computer role in engineering, especially electrical engineering. For example in (Anh Vu, 2018), the author discusses industrial revolution 4.0 that has brought challenges and numerous opportunities to economy in general, and university education in particular as current industrial age demands data analysis and proof based on information analysis and synthesis, innovative skills, and decision making. The author (Anh Vu, 2018) clarifies relationship between Industry 4.0 and education 4.0, to build and innovate academic curriculum with CDIO methodology using CDIO standards. In the work (Ramirez-Mendoza, et. al., 2018), the authors propose a new curriculum for engineering education that is based on analysis of different and essentially relevant documents and references that highlight the need to required generation of professionals to ensure development of competencies and knowledge in this fourth industrial revolution. To witness precipitous changes in 21st century, the authors (Bongomin, et. al., 2020) discuss paradigm shift (industry 4.0) where main driver is the technology fusion and that science fictions have been transformed into science facts. The study (Bongomin, et. al., 2020) investigates disruptive technologies of industry 4.0, and highlights thirteen (13) key technologies to exemplify required professional skills. The professional skills needed in industry 4.0 environment are also investigated in (skun, et. al, 2019), where authors discuss adapting higher education to industry 4.0 requirements, particularly the engineering education. A roadmap is also presented (skun, et. al, 2019) to transform curriculum development, lab concept, and student activities in line with industry 4.0 environment such as Internet of Things, Internet of Services, Physical Internet, and Cyber-Physical Systems.

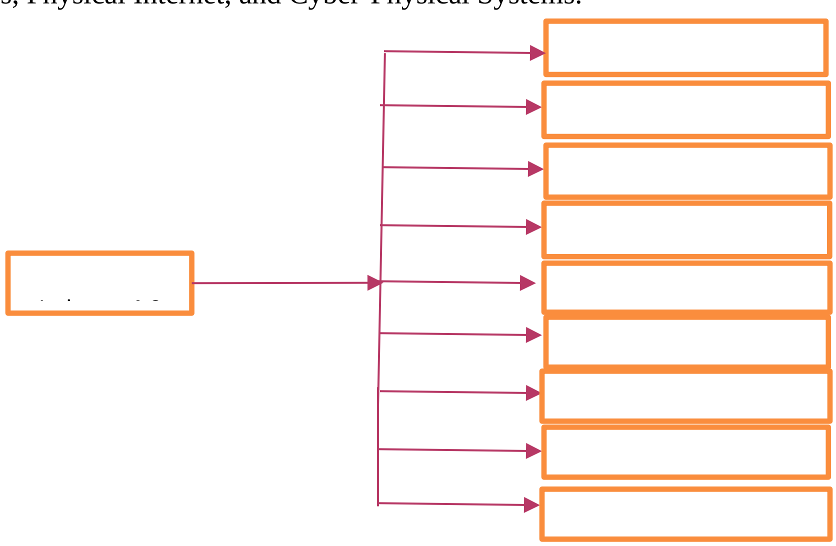

Figure 1: Industry 4.0 Technologies

In 2017, the UAE Government launched the strategy [16] for the Fourth Industrial Revolution (4IR) during the Government's Annual Meetings. The strategy targets to increase contribution to the national economy by means of future emerging and applied technologies. It outlines the direction by providing intelligent services as a model for sustainability. The strategy focuses on education, artificial intelligence, intelligent genomic medicine, and robotic healthcare. The technologies highlighted in industry 4.0 strategy (the-uae-strategy-for-the-fourth-industrial-revolution, accessed July 31, 2020) are shown in Figure 1. The Related to education, smart learning experience is deemed necessary to develop advanced technologies such as science, nanotechnology, and artificial intelligence. Regarding electrical engineering education, the strategy document refers to robotics, nanotechnology, artificial intelligence, and Internet of things.

The outlook of GCC region companies is such that the companies have already started using 4th generation industrial technologies. A Middle East based aerospace manufacturing company, for example, has already started establishing a factory in which product traceability, its automation and feedback will be a norm. In retail sector, new technology such as micro-location is adopted to track product flow and the consumer. The added advantage envisaged here is to identify high value customers and keep track of staff interaction with such customers.

Higher education institutions in UAE have been somewhat slow to curriculum change and teaching methods, meaning students are likely to fall behind the pace of technological change. This also means that a gap exists between what is taught at university, and the technological skills employers require from graduates. This is pretty much evident, if we look at curriculum of engineering programs in UAE universities, particularly electrical engineering (UoS, UAEU, AUS;, KU, ADU websites, accessed July 5, 2020). We find that universities are not adequately prepared in inculcating skill demands of today's industry, which, in other words, highlights that engineering education and skills development lacks adaption to technological pace of today's industry.

3. Current Curricula in UAE Institutions and Directions

There are many potential disciplines that exploit the computer related skills of EE graduates. Amongst many, computer related skills enable EE graduates in the design of computer-based systems to address specialized and application specific needs. Applications are found in various industries, including the telecommunications, computer, manufacturing, aerospace, power production, defense, electronics industries, etc. A number of research works to analyze electrical engineering programs have already been investigated (Memon, 2007; Memon and Harb, 2009, Memon and Khoja, 2009). There are a number of UAE universities, which offer undergraduate degree in electrical engineering, namely Khalifa University (KU), University of Sharjah (UoS), Abu Dhabi University (ADU), American University of Sharjah (AUS), United Arab Emirates University (UAEU), etc. All of these were investigated in depth and breadth to find out how computer courses are embedded within its core and elective components to strengthen needed hardware and software skills of EE graduates. The breadth here means how many computer courses (in credits) are part of EE program, whereas depth means courses that are integrated to create deeper software skills or hardware/embedded skills. Table 1 lists (computer area) core and elective courses offered in well-known UAE universities, whereas Table 2 details depth and breadth in number of computer courses based on Table 1. Table 3 highlights whether courses offered in software and hardware areas are chained (/closed) or open (for skills development); and availability of at least 2-3 other independent courses to inculcate specific skills or support further graduate studies.

Table 1: Core and Elective courses

	KU	UoS	ADU	AUS	UAEU
Programming	x	x	x	x	x
Digital (Logic) Design & Laboratory	x	x		x	x
Computer Organization/Digital Design	x		x		x
Microprocessors & Laboratory	x		x		x
Embedded systems/Microcontroller based Design	x	x		x	x
Java Programming Applications	x				x
Digital Image Processing	x	x			x
Special/Selected Topics	x				x

Table 2: Depth and Breadth in number of computer courses' credit hours

	KU	UoS	ADU	AUS	UAEU
Breadth (Core/Elective)	12/15	12/03	09/03	11/06	14/12
Depth in Core (Hardware/Software)	08/04	08/03	06/03	08/03	11/03

Table 3: Closed or Open-Ended courses (O: Open; C: Closed; N: Not existing (i.e., one course), E: Existing)

	KU	UoS	ADU	AUS	UAEU
Programming level 1 and 2 Laboratories/courses	O	N	N	N	O
Digital Logic & Organization/Digital Design	N	N	N	N	C
Microprocessor & Microcontroller/Embedded systems	N	N	N	N	C
2-3 Independent courses	E	E	N	N	E

Table 2 shows that Khalifa university and UAE university have relatively more breadth in its offering of core and elective computer courses compared to other three universities, whereas UAEU, AUS, UoS and KU have relatively similar depth in core, and ADU with the least. Table 3 groups the courses in different areas. It shows that only KU and UAEU have open ended software courses, and that other universities do not emphasize depth in software area. In hardware, none of the universities except UAEU have more than one course in hardware area(s). For independent course, only KU, UoS and UAEU offer skills development in other area of computing. If we combine Figure 1 and Table 1, the pace of curriculum regarding industry 4.0 revolution becomes clearer. It is illustrated in Figure 2. The objective is to see which of the technologies are addressed in current curriculum in most of well-known UAE universities.

The (x) sign within boxes shows that corresponding technologies are not addressed in curriculum of any of the specified universities in UAE. Some of the technologies, as indicated in Figure 2, are explicitly covered by a typical computer science program. It is also clear from Figure 2 that ADU does not cover any of industry 4.0 technologies, AUS and UoS address only one technology through embedded systems/microcontroller-based design course, whereas UAEU covers two technologies. KU covers relatively more technologies, and this has been made possible through common elective courses offered through department of electrical engineering and computer science.

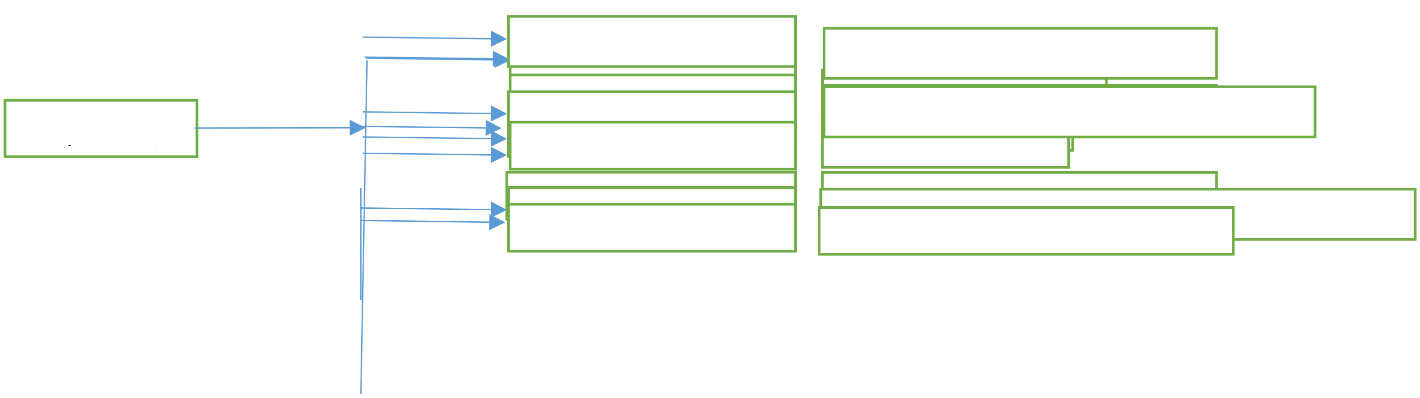

Figure 2: Industry 4.0 Technologies and Curriculum in UAE Universities

4. Results and Discussion

As discussed earlier in section 2, if we span UAE industries, industry 4.0 technologies are already prevalent in the field. Specially, the IT industry which spans use of Internet has seen use of bots for faster and simpler professional services. The power generation and maintenance has seen use of remote control and automation to save cost and faster response time. But, if we look at curriculum of a sample of well-known UAE universities, we find that programs are still traditional in depth and breadth, and mostly lack to build skills needed to face industry 4.0 compliant industries. Generally speaking, there is an awareness of industry 4.0 challenges felt within academia of UAE universities, and relevant courses have been planned and in some universities in approval and accreditation stages. But these courses are general and planned mainly at general level common to all engineering disciplines. The prominent proof of this is that only one course is offered at most of the UAE universities to develop core or higher-level programming skills. To conduct comparative analysis, tables were built to understand core and elective requirements of electrical engineering programs of different universities along with depth and breadth in each degree program.

The Industry 4.0 will not only bring a change in the factories and labor market, but it is going to affect professional skills in terms of qualified graduates. The combination of real and virtual world is bringing change in education with some risks. These risks need to be analyzed and evaluated by some risk assessment matrix. The recent analysis of Automation (McKinsey and Company's, accessed November 13, 2020) predicts that nearly 51% of the total job would undergo automation. This analysis brings big shocking blow to graduates and educators. If these risks are not evaluated and addressed on time, the unemployment situation would worsen and could lead to disaster in various countries in the coming future.

There is another direction, where this Industry 4.0 may lead us. The Industry 4.0 encapsulates the industrial processes that are monitored, controlled, and coordinated by a computing & communication core. To enable this, engineering professionals need to expand design skills to cover interoperability, virtualization and decentralization, As discussed in work (Jeganathan, et. al, 208), this requirement maps to educational platform to transform engineering skills to meet the demands of Industry 4.0. This work (Jeganathan, et. al, 208) also projects discipline-independent framework for the curriculum of EE 4.0 instead of present discipline-dependent curriculum – tentatively called Engineering 4.0 discipline. Thus, each graduate will have same basic skills of all disciplines with professional ethics. This way, learning outcomes, measured will be mapped to skill-based requirements of Industry 4.0.

There can typically be two approaches to pace up to industry 4.0 challenges: Hard and Soft. In hard approach, whole electrical engineering curriculum is to be revamped to embed industry 4.0 technologies. With this approach, the student skills after graduation will meet the expectations vis-à-vis professional challenges. In soft approach, either elective course basket is increased to enable students to select industry 4.0 relevant courses or students are encouraged to select courses from computer science department as open electives to satisfy their needs to meet professional challenges. The approach used by Khalifa University in its electrical engineering program follows closely to this soft approach by offering common electives from both electrical engineering and computer science. At Khalifa University, this obviously was possible by offering both electrical engineering and computer science programs at common platform as department of electrical engineering and computer science. Other variations may also be devised to achieve the same common goal. The examples are: merging electrical and computer engineering departments/programs; widening the common/general engineering courses for all engineering disciplines, etc. The contents of these courses, however, may be left to the evolution to match the pace of local and international accreditation and benchmarking. This is the area, which needs further research.

5. Conclusions and Future Directions

An analysis of electrical engineering program courses in various UAE universities was presented vis-à-vis computer courses considering industry 4.0 professional challenges. There are more than twenty engineering institutions in UAE. Out of this lot, five well developed universities were investigated for recent changes in curriculum regarding engineering education specifically electrical engineering. It turned out that, though direction has been set for Education 4.0, and some general courses have been set but core and electives in electrical engineering are still at Education 3.0 level. The reasons, it seems, may be due to lack of qualified faculty and instructors and support from governmental organizations. Though agreed at higher levels of educational management that the transition from Education 3.0 to Education 4.0 will be gradual, but this area needs further research to pinpoint curriculum priorities for streamlining the implementation of Industry 4.0 directives of the federal government Industry 4.0 strategy. In nutshell, the institutions need creative and innovative minds to embrace risk and enable our educational system to respond effectively - to bridge Education 3.0 to Education 4.0.

As far as future of students is concerned, we all understand that with upcoming drastic changes due to Industry 4.0 technologies, many challenges will surface that are going to hit educational institutions in near future especially labor market. These challenges will force universities to fundamentally innovate to shift from traditional educational to smart disciplines along with training programs to adapt to job market. Thus, goals will change towards focused training, development skills and students will be required to have creative thinking skills to meet demands of society.

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