

Assessment of the Technical Skill Requirements for Industrial Engineering Students Towards Careers in Industry 4.0

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ABSTRACT

The Fourth Industrial Revolution is an era inspired by the invention of the internet and automation technology. Building on the Third Industrial Revolution - Digital Revolution, Industry 4.0 is typified by a combination of technologies of the physical, digital, and biological spheres in order to enable autonomous smart operations amongst machines, products or devices, internet, and people. Industry 4.0 is characterized by a change in technology, it is also characterized by a change in skills or occupation due to the need for skillful workers in the evolving industry. With the rapid change in technology, it has become important for industrial engineers to learn and relearn technical skills in order to be employable and productive in the labor market. The United States Department of Labor's Occupational Outlook Handbook projected a growth of 5% in Industrial Engineering which will produce sufficient job opportunities for students in the field. Various stakeholders have taken it upon themselves to study these technological changes and its impact on engineering education and occupation, however, despite these interventions, there are concerns about the low rate of adoption of the proposed intervention in schools compared to the frequency of technological change.

In this study, two surveys directed at engineering experts and engineering students are conducted, the students survey is conducted mainly to investigate students' perception and knowledge of Industry 4.0 and related technologies however the experts' survey form the basis of the research works and results of this study; the results of the survey are analyzed, and the skill gaps in the labor market is identified. Some technical and transversal skills were identified, this would drive my recommendation for curriculum

inclusion through industry 4.0 inspired courses or programs for Industrial Engineering department at Eastern Mediterranean University.

Keywords: Big Data, Cloud Computing, Courses, Curriculum, Education, Internet, Industry 4.0, Industrial Engineering, Industry Experts, Industrial Revolution, Skills, Surveys.

ÖZ

Dördüncü Sanayi Devrimi, internet ve otomasyon teknolojisinin icadından ilham alan bir çağdır. Üçüncü Sanayi Devrimi- Dijital Revrimi üzerine inşa edilen Endüstri 4.0, makineler, ürünler veya cihazlar, internet ve insanlar arasında otonom akıllı operasyonları mümkün kılmak için fiziksel, dijital ve biyolojik alanların teknolojilerinin bir kombinasyonu ile karakterize edilir. Endüstri 4.0, teknolojiye bir değişiklik ile karakterize edilir, aynı zamanda gelişen endüstride yetenekli işçilere duyulan ihtiyaç nedeniyle beceri veya meslekte bir değişiklik ile de karakterize edilir. Teknolojiye hızlı değişimle birlikte, mühendislerin işgücü piyasasında istihdam edilebilir ve üretken olabilmeleri için teknik becerileri öğrenmeleri ve yeniden öğrenmeleri önemli hale gelmiştir. Amerika Birleşik Devletleri Çalışma Bakanlığı'nın Mesleki Görünüm El Kitabı, Endüstriyel Mühendislik'de %5'lik bir büyüme öngördü ve bu da alandaki öğrenciler için yeterli iş fırsatları üretecek. Çeşitli paydaşlar, bu teknolojik değişiklikleri ve mühendislik eğitimi ve mesleği üzerindeki etkisini incelemeyi kendilerine görev edinmişlerdir, ancak bu müdahalelere rağmen, önerilen müdahalenin okullarda teknolojik değişimin sıklığına kıyasla düşük oranda benimsenmesi konusunda endişeler vardır.

Bu çalışmada, mühendislik uzmanlarına ve mühendislik öğrencilerine yönelik iki anket uygulanmakta, öğrenci anketi esas olarak öğrencilerin endüstri 4.0 ve ilgili teknolojilere ilişkin algı ve bilgilerini araştırmak amacıyla yürütülmekte, ancak uzman anketi araştırma çalışmalarının temelini oluşturmakta ve bu çalışmanın sonuçları; anket sonuçları analiz edilmekte ve işgücü piyasasındaki beceri boşlukları tespit edilir. Bazı teknik ve enine beceriler tanımlandı, bu da endüstri mühendisliği bölümü için

endüstri 4.0'dan ilham alan kurslar veya programlar aracılığıyla müfredatın dahil edilmesi için önerimi yönlendirecekti.

Anahtar Kelimeler: Büyük Veri, Bulut Bilişim, Dersler, Müfredat, Eğitim, İnternet, Endüstri 4.0, Endüstri Mühendisliği, Endüstri Uzmanları, Sanayi Devrimi, Beceriler, Anketler.

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LIST OF ABBREVIATIONS

3D	Three-Dimensional
AR	Augmented Reality
CAD/CAM	Computer Aided Design/ Computer Aided Manufacturing
CPS	Cyber-Physical Systems
EMS	Energy Management System
ERP	Enterprise Resource Planning
GPS	Global Positioning System
HMI	Human Machine Interface
I 4.0	Industry 4.0
IE	Industrial Engineering
IoS	Internet of Services
IoT	Internet of Things
LIMS	Laboratory Information Management System
MES	Manufacturing Execution System
MOM	Manufacturing Operations Management
PLC	Programmable Logic Controller
RFID	Radio-frequency Identification
SAP	Systems Applications and Products
SCADA	Supervision Control and Data Acquisition

Chapter 1

INTRODUCTION

1.1 Overview

Technology has constantly been developing over the past century, in the last two decades, the world has witnessed technological evolution like never before. This evolution is now visible in every area of human life. Televisions, mobile phones, cars, machines, aircrafts, warfare, even education are not what they used to be. Series of technological and social changes influenced the industrial revolutions which began in the 18th century. The inventions of the first industrial revolution and subsequent industrial revolutions was borne out of necessity. The key features of industrial revolutions are acquisition of knowledge, transfer of knowledge, experimentation, inventions, and improvement of past inventions. The evolution of education, especially engineering education was influenced by technological advancements during the industrial revolution eras. These changes greatly influenced the labor market and the skills of workers over the centuries. The connection between education and skills in the labor market during the industrial revolutions has been a topic of public debate over the years and has been studied by various scholars. Bessen (2015) analyzed the relationship between technology and skills acquired through formal education, training, and experience. According to him, new technologies create demand for workers with higher degree of cognitive ability, demonstrated by rapid learning and mastery of new skills. This study is consistent with past studies by (Berman, Somanathan, & Tan, 2005; Ariel & Jonathan, 2010).

Also, assessment of the extent to which the technologies of the 1st and 2nd eras of the Industrial Revolution had influenced the increase or decrease in demand for skills in production or manufacturing has been studied. Paul, Rowena, & Morin (2015) in their study found that electrification caused an increased shift from agriculture to manufacturing in the United States during the early industrial revolutions. According to U.S. Department of Labor Bureau of Labor Statistics, the causes of decrease in percentage of manufacturing workers around 1960 included increased shift to automation and a service economy, also the subcontracting of manufacturing jobs overseas (Wasfy et al., 2013).

With majority of the change in skill demand in the textile industry during the nineteen centuries as a result of mechanization, there was financial lift of workers as they acquired skills that earned them more pay (Bessen, 2011). In recent studies of the skills and education required in the industry in today's world of the Fourth Industrial Revolution (Industry 4.0) which is characterized by high degree of automation and interconnectivity. Robertson & Newman, June (2007) examined the response to changes in job requirement in the electronics industry as a result of products evolution over the years. Marbouti & Lynch (2014) investigated the skill competency of PhD students in Science Technology Engineering and Mathematics (STEM) in jobs in industry, consulting, or government - they suggested the addition of specific curricula, professional development classes, and seminars to address identified shortcomings.

In 2016, World Economic Forum (WEF) looked at the change in employment and skills for the future as they predicted that by 2020, the Fourth Industrial Revolution would influence advancement in advanced robotics, autonomous transport, Artificial Intelligence and machine learning, and biotechnology (WEF, 2016). In the 2020

edition of this report, they described the influenced of the Fourth Industrial Revolution and COVID-19 pandemic in the advancement of digitization, remote working, and e-commerce (p. 16). They projected that by 2025, companies would have adopted technologies of Industry 4.0 such as cloud computing by 17%, data analytics by 2%, and Internet of Things (IoT) by 9% (WEF, The Future of Jobs, 2020). Ultimately, these changes would occur across all industries, manufacturing will get automated hence justify the need for reskilling and upskilling of industrial engineers in these sectors.

1.1.1 Introduction to the Industrial Revolutions (IRs)

The industrial revolution is the series of socio-economic changes in the society that is characterized by advancement in technology and accelerated rate of inventions. There are different views about the Industrial revolutions. Mohajan (2019) opined that the First Industrial Revolution was more relentless and successful, he said

the Industrial Revolution was the transition from human and animal labor technology into machinery, new chemical manufacturing and iron production processes, improved efficiency of waterpower, the increasing use of steam power, and the development of machine tools (p. 2).

Clark (2001) ascribed no significance to the events around the era of the Industrial Revolution, he argues that there was nothing special about the events of 1770 and later in England; and it was just a continuation of the series of episodic spurts of growth that had been occurring in Europe since the Middle Ages (p. 4). Agarwal & Agarwal (2007) explained Industrial Revolution in three ways; a rapid growth of certain sectors of the manufacturing industry, a structural shift in the economy, and an unceasing expansion in national income between mid-eighteenth and mid-nineteenth centuries. According to them

Industrial Revolution can be defined as the structural shift of the large proportion of the population from agricultural to manufacturing and mining sector, which caused a growth in manufacturing sector, and ultimate increasing the national income (p. 1062).

1.1.1.1 The First Industrial Revolution (Industry 1.0)

Industry 1.0 which started around the 1760s was marked by use of steam and coal-powered machines, replacing the use of hands. Prior to this time, the local crafts people such as metal workers, potters, millers, and weavers used traditional skills and muscle power to hand-craft items in tiny shops and cottages, with the invention of the factory system, arguably the most important invention of this period, manufacturing was done by machines which was easier and efficient (Leijonhufvud, 1986).

The first industrial revolution occurred first in England and led to enormous expansion of cities, roads, and factories, coal replaced wood, steam replaced water wheels and livestock, the use of muscle work reduced (Spielvogel, 2014); all these led to an upgrade from the rural lives that most British lived. Landes (1969) stated

Coal and steam, therefore, did not make the Industrial Revolution; but they permitted its extraordinary development and diffusion. Their use, as against that of substitutable power sources, was a consideration of costs and convenience (pp. 99).

Industry 1.0 also brought development in the production process of cotton, iron, wool, and coal leading to an improvement in the economy of England. More inventions and improvements to innovations such as the steam engine caused advancement in the mining factories, breweries, cotton factories and transportation through invention of waterways, bridges, railway lines and roads (Padmanabhan, 2012; Forrester, 2019).

1.1.1.1.1 Skills of the First Industrial Revolution

Before the industrial revolution, people mainly had craft skills, production activities were performed with hands. People had jobs such as blacksmiths, cart makers, forge masters, seamen, wheel makers, potters, weavers, millers, knitters, nail makers, straw plaiters, tailors, shoemakers, and lace makers. These jobs do not require much prior

training, nor do they strictly require skill. Bythell (1983) in his account of production during the pre-industrial revolution said that

Work merely involved the monotonous repetition of a few simple movements of the finger; and because the work is unskilled and undemanding it was particularly suitable for women and children” (p. 20).

With regards to production, (Spielvogel, 2014) believed that there was a complete shift from cottage system to factory system as workers had to learn or acquire new skills as manual labor was gradually replaced with machines. However, (Bythell, 1983) argues that the cottage system did not expire, rather it enlarged and continued on until the late nineteenth century, hence strengthening his stance that both systems did not compete but complemented each other. Supporting Bythell’s stance is (Mokyr, 2001) statement

Most firms did not switch abruptly from the domestic system to a factory system but continued to farm out some processes to domestic workers, until mechanization and technological complexity had sufficiently expanded to make it worthwhile to bring the workers under one roof (p. 4).

Table 1: Innovations of the First Industrial Revolution.

Year	Innovation	Innovator
1709	Coke from Coal	Abraham Darby- Iron maker
1712	Steam Engine	Thomas Newcomen- Ironmonger
1733	Flying Shuttle	John Kay- Inventor
1765	Spinning Jenny	James Hargreaves- Weaver
1775	Improvement of the steam engine	James Watt- Engineer- Chemist
1792	Illumination with Coal gas	William Murdoch- Engineer
1793	Cotton Gin	Eli Whitney- Engineer
1821	Electric Motor	Michael Faraday- Scientist
1839	Screw-propelled Steamship	John Ericsson- Engineer

While some innovators of the first industrial revolution were hardly skilled in the area of their innovation, others had some form of informal training through apprenticeship in areas related to their inventions. Table 1 shows some of the major invention of Industry 1.0 and the skills attributed to their inventors. Most of the skills during this era were acquired through knowledge transfer and numerous experiments as because inventors were usually craftsmen who had prior contact with engineers and other unknown innovators who tried to invent something similar in the past. Others relied on self-education to gain the skill required for their envisioned inventions.

1.1.1.2 The Second Industrial Revolution (Industry 2.0)

Industry 2.0 which started in the 19th century between 1870 and 1914, this period witnessed a breakthrough in electricity, petroleum, and steel. Also, advancements occurred in iron, rail, communications, internal combustion engines, rubber, and fertilizer (Landes, 1969). Technological advancements that played a major role in the second industrial revolution go back to the late 19th century. The first industrial revolution paved the way for new innovations in the era of the second industrial revolution, between 1920s and 1930s the economy began to experience rapid progress in productivity based on these inventions (Crafts, 2004).

A major factor of consideration is that the continuous accumulation of knowledge - a more organized and formal knowledge extended the somewhat limited and localized achievements of Industry 1.0 to a much broader range of industrial activities and products across countries like Belgium, USA, Germany, UK, France, and Italy. The innovations in chemistry during this era included the discovery of alloys, fertilizers, explosives, polythene, synthetic plastic, and rubber. Explosives were used in constructing quarries, oilwells, and tunnels; products such as combs, knife handles,

piano keys, and baby rattles were manufactured through chemical processes (Mokyr & Strotz, 1998).

Electricity was another innovation of this era that shaped the economy. Electricity became the major and preferred source of light and power, the creation of light bulbs in 1879 by Thomas Edison replaced the use of candles and gas lamps to light homes and factories when activities extend beyond daytime (Gordon, 2012). With electrical machine gradually replacing steamed and coal-powered machines, factories adopted continuous production system and produced mass products (Toms & Wilson, 2014). The development and implementation of continuous-flow production and assembly lines in the automobile industry (Landes, 1969) made mass-production possible at low price such that speed of operations were controlled and time wasted by workers between operations is minimized (Mokyr, 1998). Mass production meant mass distribution, there were marketer from mass retailer, chain store who procured products directly from the manufacturers and sold to smaller retailers and final consumers. During the second industrial revolution, industries demanded the need for more efficient and effective deployment raw materials, products, and production processes, also the expansion of its workforce and division of labor (Chandler, 1990).

1.1.1.2.1 Skills of the Second Industrial Revolution

Transition into the era of Industry 2.0 brought a lot of changes in science and technology, innovations were more technical and effective. Technical skills were more sought after, engineering and science was applied to construction, production, fabrication, chemistry, and trade etc. Skills that were nonexistence in the previous era began to surface, these new skill requirements were informed by the changes in the composition of occupations. The quality and quantity of training or skill acquired depended on the location of birth/residence of the worker since the kind of innovations

and advancement differed with countries, more people attended formal schools, there was a more structured and organized form of training or knowledge acquisition, especially in specific areas of technology. Chin, Juhn, & Thompson (2004) remarked

Engineers attained their positions only after extensive training, including through apprenticeships and technical college. Certification required meeting the training standards as well as passing written and oral exams (p. 4).

These exams were enforced by the government not employers (Burton, 1990), creating a professional structure for careers in the shipping industry (Khan, 2016). Application of electricity to plant and machine design required new and continuous learning; as opportunities opened, there was also continual innovation in processes and procedures within an existing plant to improve overall production efficiency.

Table 2: Innovations of the Second Industrial Revolution.

Year	Innovation	Innovator
1835	Telegraph	Samuel Morse
1852	Mechanized passengers' elevator	Elisha Otis
1853	Bessemer process	Henry Bessemer
1867	Typewriter	Christopher Sholes
1869	Compressed air brake	George Westinghouse
1876	Telephone	Alexander Graham Bell
1877	Phonograph	Thomas Edison
1879	Electric bulb	Thomas Edison
1885	Combustion engine in automobile	Karl Benz
1893	Gasoline- powered automobile	Charles and Frank Duryea
1908	Assembly line to produce automobile	Henry Ford

Engineering skills grew in demand, industry specific skills in Ceramics, Mining, Precision Instruments, Commerce, Printing, Construction, Brewing, Surveying, and Food processing also grew (Hirschman & Mogford, 2009). Table 2 shows the major inventions of Industry 2.0, these inventions aligned more to the skills of the inventors. Inventors relied on the combination of formal, semi-formal, apprenticeship, and extra-curricular activities for their works. Experimentation also played a huge role in the birth of these innovations (Khan, 2016). Formal education caused an increase in technical skills, there was also the emergence of professional skills such as management, supervision, record keeping, problem solving, critical thinking, etc.

1.1.1.3 The Third Industrial Revolution (Industry 3.0)

The Third Industry Revolution, also known as the Digital Revolution, started in the 20th century around the 1960s. It is often referred to as the computer era. Rifkin (2015), an economist however coined the concept to describe the technological and social revolutions that happened during this period. With its origin from USA, Japan and Europe, Industry 3.0 can be seen as the economic revolution brought about by the combined effect between renewable energies, information, and telecommunication (ICT) technologies. This period was marked by the automated machines invented with electronic devices like transistors, integrated circuits, it focused on the diffusion of microelectronics and internet (Taalbi, 2019). Computers and digital systems enabled smart processing and information exchange, also the invention of transistors, microprocessors, robotics, and automation.

Industry 3.0 is driven by technological advancements in manufacturing, distribution, and energy (Roberts, 2015). The spread of automation and digitization through the use of computers coupled with the invention of the internet led to new technologies that enabled the automation of many industrial processes and activated radical business

models all over the world. The 1980s recorded ventures into Computer-Aided Design and Manufacturing, an expansion on the previous advances in robot or control systems technology. With focus on factory automation, consumer electronics, telecommunication, and data communication, the third industrial revolution created great opportunities in infrastructure industries.

The extent of Industrial 3.0 influence in manufacturing is enormous: the interaction between facets of the industry is easier with the help of the internet and automation, different players in businesses and social enterprises, even individuals can connect, produce, and exchange goods and services with each other without the need of physical middlemen (Rifkin, 2015). Key advancements in manufacturing were the improvement in processes and practices. 3D printing, also often referred to as Additive Manufacturing replaced the traditional centralized manufacturing method. 3D manufacturing finds its application in industries that produce intricate and high precision materials such as aviation, automobile, healthcare, architecture, arts, construction, and jewelry (The Economist, 2012). Some technological inventions of this era are shown in Table 3.

1.1.1.3.1 Skills of the Third Industrial Revolution

The technologies of Industry 3.0 changed the way things were done in the industry. The changes in the nature of industrial practices and processes started as industries partially shifted to worker-less production and internet-based, information and digital machineries (Roberts, 2015). According to Kapás (2008), these information technologies encouraged industries to change their production methods, leading to the adjustment of how work is organized within all operational departments of the industry.

Table 3: Innovations of the Third Industrial Revolution

Year	Innovation
1947	Transistors
1969	Internet Protocols
1971	Microprocessors
1973	Ethernet
1986	Programmable Logic Controllers (PLCs) are linked to Personal Computers.
1991	The First 'Web Page' is created
1997	Wireless Machine-to-Machine Technology becomes prevalent in Industrial settings.
1998	The Google Search Engine was built
1999	The Internet of Things Term was coined
2004	The Era of social media began
2005	Big Data was coined
2008	Blockchain and the First Cryptocurrency ever invented are introduced to the World

Organizations were built on cross-functional autonomous teams with well-defined tasks, observable outputs, or projects (Zenger, 2002). Administrative tasks and production processes in the industry were integrated in computer software and performed by automated activities.

Cognitive skills, non-cognitive skills and social skills were recognized as requirements for workers in the industry. With Technology serving as a skill augmenting platform to complement the tasks of low-skilled or high-skilled workers (Acemoglu & Autor, 2010). There are resources to measure cognitive, creative, technical, and social skills within engineering specific occupations, examples of such resources are Dictionary of Occupational titles (DOT), Standard Occupational Classification System (SOC), and Occupational Information Network (O*NET) measurements of occupational skills.

The ability to exploit knowledge through intellect i.e., problem solving, innovation, and critical thinking; and direct command i.e., authority and supervision is also crucial to accumulating and applying new skills (Cohen & Levinthal, 1990; Liu & Grusky, 2011). Liu & Grusky (2011) also opined that in contrast to technical change i.e., Industrial Revolution, being the main force behind changing skills in this era, skill-biased institutional change is the driving force (p. 35). Also supported by (Card & DiNardo, 2002; O'Rourke, Rahman, & Taylor, 2007; Blinder, 2008 and Vivarelli, 2011).

1.1.1.4 The Fourth Industrial Revolution (Industry 4.0)

Industry 4.0, the Fourth Industrial Revolution is what we are experiencing in today's world in terms of technological, social, and economic advancements. This era is inspired by the invention of the internet and automation technology of Industry 3.0, and it is characterized as a " smart" network of machines, products or devices, internet,

and people that exchange information autonomously and work in association with the physical world around them (Shu, Lee, Aziati, & Ahmad Nur Aizat, 2018). The idea of Industry 4.0 is to exploit the potentials of concepts such as the use of internet and IoT, integration of technical and business processes, digital mapping and virtualization of the real world, and smart factory (Rojko, 2017).

Industry 4.0 is the connection of physical assets and advanced digital technologies such as Internet of Things (IoT), Artificial Intelligence (AI), robots, drones, autonomous vehicles, Additive manufacturing, cloud computing and nanotechnology (Mohd, Fauzi, Nor, & Muhamad, 2016; Roblek, Maja, & Alojz, 2016) to connect, analyze, and process information that aids organizations, consumers, and society make more intelligent, flexible, and tactical data-driven decisions (Deloitte, 2020).

Industry 4.0 takes its origin from Germany in 2011 during a government project to transform industrial manufacturing through digitalization and exploitation of potentials of new technologies with the aim of sustaining Germany's top influence in machinery and automotive manufacturing (Roblek, Maja, & Alojz, 2016). Three German engineers Henning Kagermann (physicist and one of the founders of SAP), Wolfgang Wahlster (professor of Artificial Intelligence), and Wolf-Dieter Lukas (physicist and senior official at the German Federal Ministry of Education and Research) invented and promoted Industry 4.0 (Pfeiffer, 2017; Kagermann, Wahlster, & Helbig, 2013). Carvalho & Cazarini (2020) summarized the concept of Industry 4.0 according to the authors in the five areas below:

1. New level of socio-technical interfacing in value chains and between businesses through autonomous, self-managed production and planning processes.

2. Smart production through classifying products according to family for production optimization.
3. Customized production and flexible configuration by tailoring customers taste to the design, production, and recycling.
4. Autonomous control by designing smart production resources to workforce.
5. Product design control of production data crucial in managing product life cycle.

Industry 4.0 is basically discussed in relation with manufacturing or smart factory and industries since these are the main drivers of economic development (Deloitte, 2012). With the realization of the great possibilities of Industry 4.0 to businesses, a lot of companies have tapped its remarkable technologies; for them, this meant increasing efficiency, cutting cost, and maximizing profit through the introduction of just-in-time production, adoption of lean production strategies and outsourcing production (Deloitte, 2020). It also meant digital transformation and growth, higher production and resource efficiency (Frost & Sullivan, 2019), skills development (Asian Development Bank, 2021), smart business processes (CGI, 2017), and smart products. The possibilities with Industry 4.0 are limitless, this makes the recent research into Industry 4.0 technologies unsurprising.

The aim of Industry 4.0 is to work with a greater automation in order to achieve higher productivity and efficiency, also to connect the physical to the virtual world, thus making it a perfect business solution (Alcácer & Cruz-Machado, 2019). Leyh, Martin, & Schäffer (2017) describes Industry 4.0 as being responsible for the smart flow of the products from one machine to another in a factory while they communicate with one another in real-time.

1.1.1.4.1 Industry 4.0 Concepts

Industry 4.0 is composed of pillars such as Internet of Things (IoT), Big Data and Data Analytics, Augmented Reality, Cybersecurity, Collaborative Robots, Additive Manufacturing, Cloud Computing, Artificial Intelligence, and 5G networks. These concepts are further discussed in this section.

1.1.1.4.1.1 Industrial Internet of Things (IIoT)

IoT describes the interconnectivity between things and the internet. In the real world, “things” can be an object or a person. This network allows the exchange of information between devices in the network (Bortolini, Ferrari, Mauro, Francesco, & Faccio, 2017). Industrial Internet of Things, IIoT is the connection of industrial elements and/or machines to the internet. The concept of Industrial Internet was developed up by the General Electric company in late 2012 as a combination of physical and digital environments that connects Big Data Analytics with the Internet of Things (Rojko, 2017), it incorporates power generation and distribution, healthcare, manufacturing, public sector, transportation, and mining (Stackowiak, 2019).

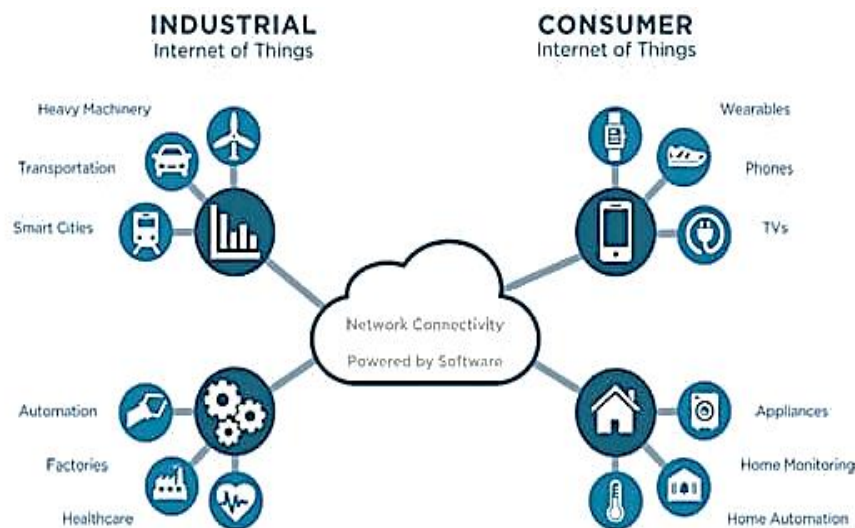


Figure 1: Industrial Internet of Things and Consumer Internet of Things.

1.1.1.4.1.2 Big Data and Data Analytics

Big Data refers to a large amount of structured, unstructured, or semi-structured data. These data are complicated and cannot be easily managed, analyzed, and/or processed. Factors responsible for this complexity are not limited to the speed with which these databases grow, the number of sources which are producing it, and the complexity of management (Alcácer & Cruz-Machado, 2019).

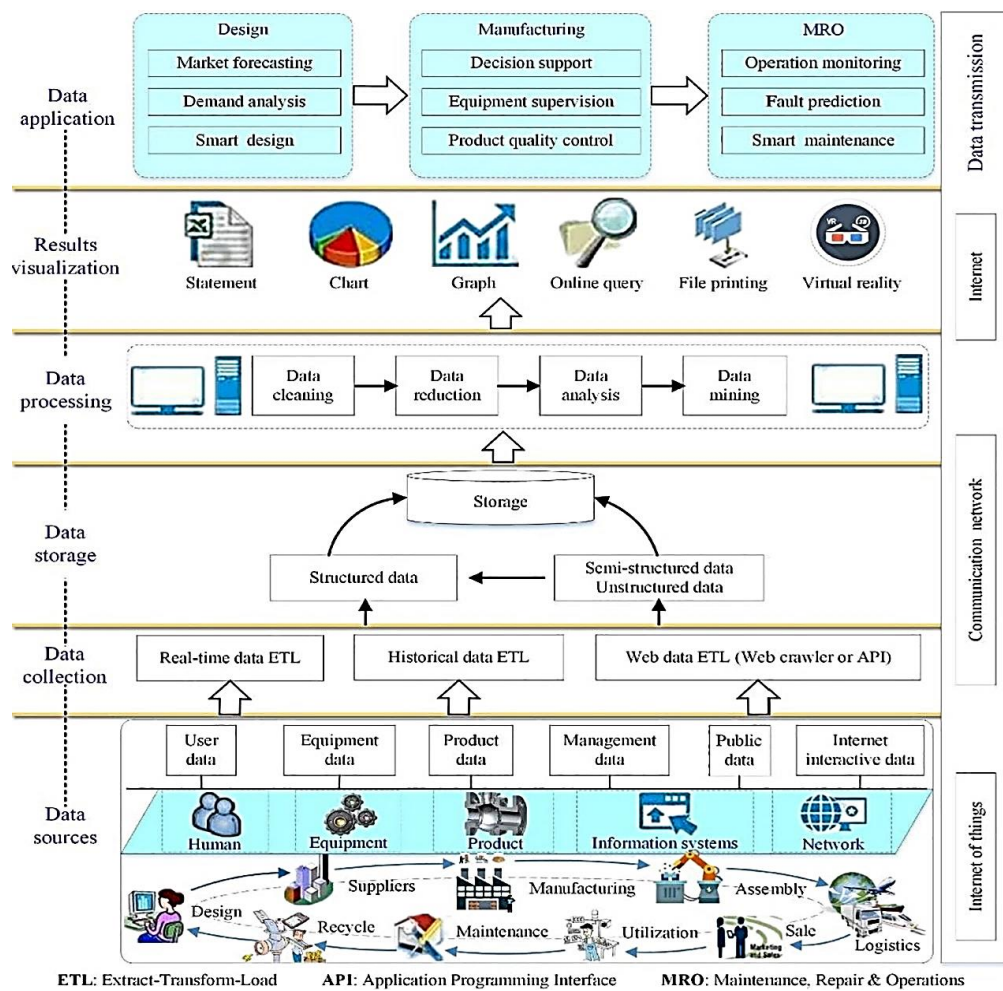


Figure 2: Manufacturing Big Data Lifecycle.

In manufacturing where there are levels of enterprise, the lower level generates data directly from machine, equipment, and operators (Mourtzis, Vlachou, & Milas, 2016). Using Cloud Computing and advanced analytics methods or tools, off-line and real-

time data are mined and analyzed; the knowledge of data enables manufacturers to understand the product lifecycle at various stages. Big Data Analytics is essential to manufacturing and mass customization of individualized market demand to production.

1.1.1.4.1.3 Simulation

Simulation is described as a process imitation over time of a system or a real-life situation. System complexities and uncertain problems that cannot be resolved with usual mathematical models can be resolved using computer simulations making it an indispensable technology to better understand the dynamics of business systems (Lachenmaier, Lasi, & Kemper, 2017). Simulation allows experiments that validates products, processes or systems design and configuration adopted in manufacturing (Mourtzis, Vlachou, & Milas, 2016), this in turn reduces production costs, decreases development cycles, and increase product quality (Rodič, 2017).

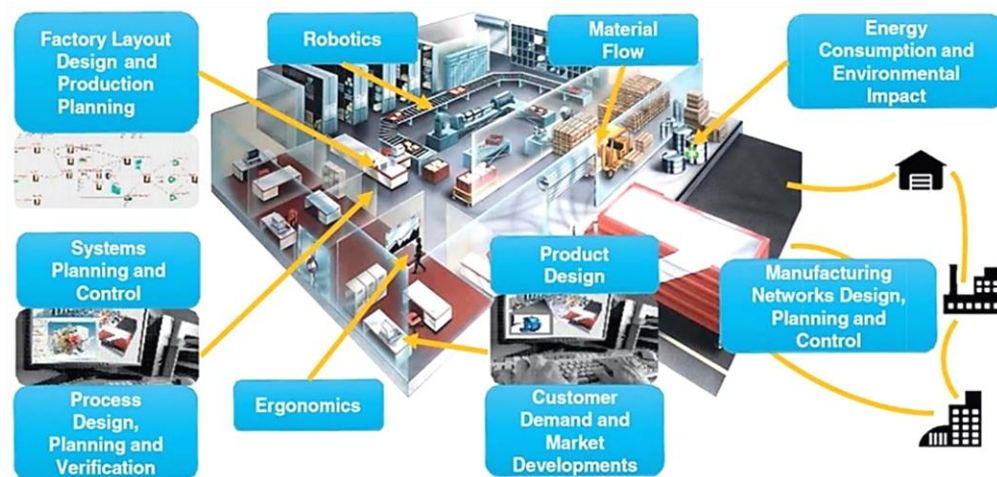


Figure 3: Domains of Simulation for Modern Manufacturing.

1.1.1.4.1.4 Augmented Reality (AR)

Augmented Reality incorporates virtual elements to physical reality in real time by using digital content as the standard tool. Digital tools such as camera, GPS system,

3D electronics and software algorithm can be used to make the connection with reality. In manufacturing, AR is used in simulation, support, and supervision; it increases an operator's perception of reality by making use of artificial information about the environment (Syberfeldt, Danielsson, Holm, & Wang, 2015). Due to its ability to replicate and reuse digital data and knowledge, AR finds application in assembly operations during product development and manufacturing operations (Syberfeldt, Danielsson, Holm, & Wang, 2015; Palmarini, Erkoyuncu, Roy, & Torabmostaedi, 2018).

1.1.1.4.1.5 Cybersecurity

Cybersecurity refers to the protection of individual or collective information stored on the IoT network. This system is responsible for security against software and physical threats to information of people and enterprises (Alcácer & Cruz-Machado, 2019). Cybersecurity ensures data confidentiality, data integrity, and data availability for the owners of the data in an industrial environment, hence IoT has to be built at each point of the manufacturing process for safe communications and interoperability to be assured between facilities and elements of the supply chain (Ani, Hongmei, & Tiwari, 2017).

1.1.1.4.1.6 Additive Manufacturing

Additive manufacturing is one of the pillars of Industry 4.0 that uses 3D technology in unique product design and manufacturing without the conventional waste (Alcácer & Cruz-Machado, 2019). It creates intricate parts of a product from scratch by adding one layer at a time using 3D technologies. With additive manufacturing, production can be done with superior customization with optimal material utilization and reduced manufacturing cost.

Additive manufacturing technologies can also be referred to as rapid prototyping, layer manufacturing, solid freeform manufacturing, digital manufacturing or 3D printing (Chong, Ramakrishna, & Singh, 2018). A typical Additive Manufacturing workflow consists of geometry design, computational tools, interfaces development, material design, process modeling and control tools; with application in electronics, bio-fabrication, personal products, automotive, construction, architecture, aerospace and defense (Chang, et al., 2018).

1.1.1.4.1.7 Cloud Computing

Cloud computing refers to offering and delivering certain services over the Internet based on demand. These services include servers, storage, databases, networking, software, analytics, and intelligence. In manufacturing, cloud manufacturing as depicted in Figure 4, consist of three categories of stakeholders (Liu, et al., 2019) who cooperate to maintain sustainable management of a manufacturing system, they are:

Providers - they own and provide manufacturing resources and also receive tasks from the cloud platform.

Operators - they operate the Cloud Manufacturing platform and deliver services to providers, consumers and third parties.



Figure 4: Cloud Manufacturing Model.

Consumers - they subscribe to the manufacturing computing services, submit their design, manufacturing, and/or simulation tasks to the cloud platform, and obtain the execution results for the tasks.

1.1.1.4.1.8 Artificial Intelligence (AI)

Artificial Intelligence is the model that makes it possible for machines to imitate human intelligence in performing tasks and making decisions; these machines are able to improve their performance in reaction to the data they collect. AI manifests in a number of forms through the use of computer programs to perform simple or complex tasks (Ben-Ari & Mondada, 2017). Robots with AI are adaptive and flexible enough to assist in various manufacturing processes. Dirty and unsafe industrial processes can be performed by an Autonomous Industrial Robot (AIR) or several robots in collaboration at a close proximity (Hassan & Liu, 2017). Collaborative Robots are used with humans for tasks in order to produce significant efficiency in the industrial

processes. It greatly reduces risks to the safety and health of human workers and saves the costs constructing or erecting preventive structures or systems.

1.1.1.4.1.9 Vertical and Horizontal Integration

Horizontal Integration involves high-level collaboration between several companies with similar production or value chain to form an interconnected ecosystem that exchanges information to enhance the product life cycle (Alcácer & Cruz-Machado, 2019). Vertical integration relates to the intra-business integration, it involves the collaboration and exchange of information between distinct levels of the hierarchy of a company, such as planning, production, management, HR, and commerce. Vertical integration “digitizes” all the processes or procedures within an organization and considers real-time data from all manufacturing processes such as quality, process efficiency and operations planning.

1.1.1.4.1.10 5G Networks

5G is the recent inclusion to Industry 4.0, currently in its earliest phase of deployment. 5G-enabled smart factories and cities will enable wireless interconnectivity of different systems in real time. With 5G, manufacturers will be able to automate end-to-end operations and configure new product lines or entire smart factories (Ortiz, Marroquin, & Cifuentes, 2020). With sensors, machine-controlled robots, and autonomous logistics capable of communicating and operating remotely in real time is possible through 5G.

1.1.1.4.1.11 Smart Factory

Smart factory implies an integration of shop floor decisions with supply chain and the enterprise as a whole, through an interconnected IoT environment in order to improve production processes and enhance relationships with clients. It involves the application of Artificial Intelligence (AI) and cyber-physical systems that incorporates business

processes with physical machines. Smart factory is flexible, self-optimizing in performance across a wide network. It is self-adapting to changing needs of the organization such as custom customers' demands, new markets/products/service expansion, operations, maintenance responsiveness, new processes or technologies integration, and real-time fluctuations to production.

Smart factory can autonomously run entire production processes (Deloitte, 2017). The characteristics of a typical smart factory is described in table 4. Many companies now adopt smart factory system for reasons not limited to asset effectiveness, quality control and assurance, low costs, safety, and sustainability in order to reap benefits such as increased speed to market, improved profitability, product quality, and labor force stability.

Table 4: Key Characteristics of a Smart Factory.

Connected	Optimized	Transparent	Proactive	Agile
Constantly spool traditional and location- based datasets	Dependable, forecasted production capacity	Live tools to support quick and steady decision making	Predictive inconsistency detection and resolution	Flexible scheduling and conversions

Real-time collaboration with contractors and clients	Increased asset and production efficiency	Real-time connections to client demand forecasts	Automated restocking	Implementation of product changes
Teamwork across departments	Automated production and material control with minimum human contact	Transparent customer demand order tracking	Early detection of issues with supplier quality	Configurable factory layouts and equipment
	Minimized quality and production cost		Real-time safety checks	

1.1.1.4.1.12 Cyber-Physical System

The introduction of the IoT and IoS into the manufacturing world has caused major development, businesses now have established global networks that incorporate their machinery, storage systems and production resources in a CPS. In manufacturing, IoT and CPS has enabled digital networking of maximum feasible number of elements involved in production processes, support services, and logistics such that everything from a local production line to global value chains is globally networked and locally

controlled (Monostori, et al., 2016). “Smart factories” are built on these principles to overcome the limitations of traditional mass production (Pfeiffer, 2017).

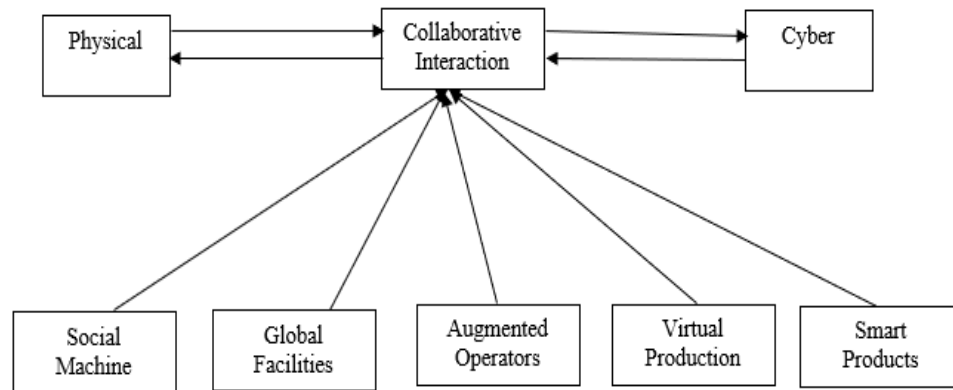


Figure 5: Interaction between Cyber and Physical Worlds.

1.2 Objective of the Study

This study draws its perspective from today world of advance computer technology and its influence on job requirements in the engineering industry and the objectives of this study are in two folds, the first is to identify additional transversal and technical skills requirements for Industrial Engineering students for successful careers in industry 4.0. The competence level for these additional skills in both Industrial Engineering students and industry experts are also highlighted in this study for the purpose of bridging the gap between knowledge taught in the university and the knowledge required for jobs in today’s era of the Fourth Industrial Revolution, this is to fulfil the second objectives of the study, to identify course contents for industrial engineering students towards successful careers in Industry 4.0. The data collected from the survey carried out in this study and the results of the analysis of these data will inform my recommendations to the department for possible curriculum adjustment or instructional change in order to improve Industrial Engineering education.

1.3 Works Completed

This section highlights the steps undertaken to accomplish the objectives of this study as stated in section 1.2. The following work was done:

1. Comprehensive research on industrial revolutions, the developments/inventions they caused, jobs they created and the technical and/or professional skills, knowledge, that they inspired.
2. Development and disbursement of online questionnaires to engineering industry experts and engineering students across all levels of education.
3. Collection of respondents opinions about the current trends in their sectors, the skills they currently deploy for their jobs and the skills that Industrial Engineering students are expected to acquire before leaving school.
4. Statistical analysis of the collected data and graphical representation of the results through the use of charts and graphs, including discussion of the results obtained.

1.4 Accomplishments

The achievements of this study are summarized as follow:

1. A meticulous literature review that discusses the past eras of industrial revolution, the kinds of inventions during these eras and how these inventions inspired new and improved inventions over the century. Also, it discusses the kinds and state of jobs or occupation and its evolution from manual to automation; and the evolution of education and industry, including the change in industrial practices or processes as a result of technological advancement.
2. Concepts of Industry 4.0 as it applies to Industrial Engineering were also discussed. Education and skill development during this era and the various study that has been done to align engineering education with Industry 4.0 and industry needs were also discussed.

3. Two online surveys were distributed to assess the reality of Industry 4.0 in the labor market and universities. This activity produced a total of 174 respondents, their answers to the questions provided justification for the contribution of this study to Industrial Engineering education.

1.5 Limitations of the Study

A few limitations were identified during this study, they are:

1. Students' general apathy to participating in surveys greatly affected this study in terms of the collected number of responses which was rather small compared to projected number, efforts to encourage and repeatedly remind students to participate in the survey yielded a little response.
2. Categorization of the industry fields for engineering experts was tricky. Engineering is a vast field with its various disciplines closely intertwined, this means that manufacturing as an industry may have electrical engineers, industrial engineers, mechanical engineers, food engineers as workers so when a respondent choose his/her industry there are chances that he/she is any of the engineer. The difficulty to distinctly separate one discipline from the other made the discuss of this study applicable beyond industrial engineering.

1.6 Thesis Outline

Chapter 1 presents the introduction into industrial revolutions; also, the innovation, education, and skills development they inspired over the past centuries.

Chapter 2 gives a wide-ranging discussion of literature reviews, theories, research papers on engineering education and skills of the Fourth Industrial Revolution.

Chapter 3 describes the methods deployed for this study- the research tools and statistical methods used for the analysis of survey data.

Chapter 4 presents information on the questionnaire survey, its preparation, and the demography of the participants.

Chapter 5 contains the results of the data obtained and discussion of the results.

Chapter 6 presents the conclusion drawn from the study and recommendations for future research on this topic.

Chapter 2

LITERATURE REVIEW

2.1 Background

Concerns about the impact of Industry 4.0 in industries has been on the rise over the years. A survey conducted by the WEF showed that Industry 4.0 would cause a reduction in full-time workforce by 2022 and new remote roles would emerge in the workforce because new technologies will drive job creation and demand for specialized skills (World Economic Forum, 2018). This is evident in the world today, according to this report, the new technologies that were likely to be adopted are depicted in Figure 6. The rapid transformation caused by the technologies of Industry 4.0 make employers to be in demand for employees with new and specialized skills (Chowdhury & Murzi, 2020; Pistrui, Kleinke, Das, Bonnstetter, & Gehrig, 2020; Sirinterlikci, 2020). The demand for these skills has caused many scholars make the call for academia to reform its pedagogical practices in line with Industry 4.0 to meet the needs of the industry. Due to the uniqueness of the technologies associated with Industry 4.0, jobs requiring human-machine interaction are in more demand.

Today, employers are not just concerned about technical skills and formal credentials, but they are also interested in the professional competences that are useful in performing job tasks. Table 5 lists core practical competences widely desired in today's workforce across all industries as reported by WEF in 2020.

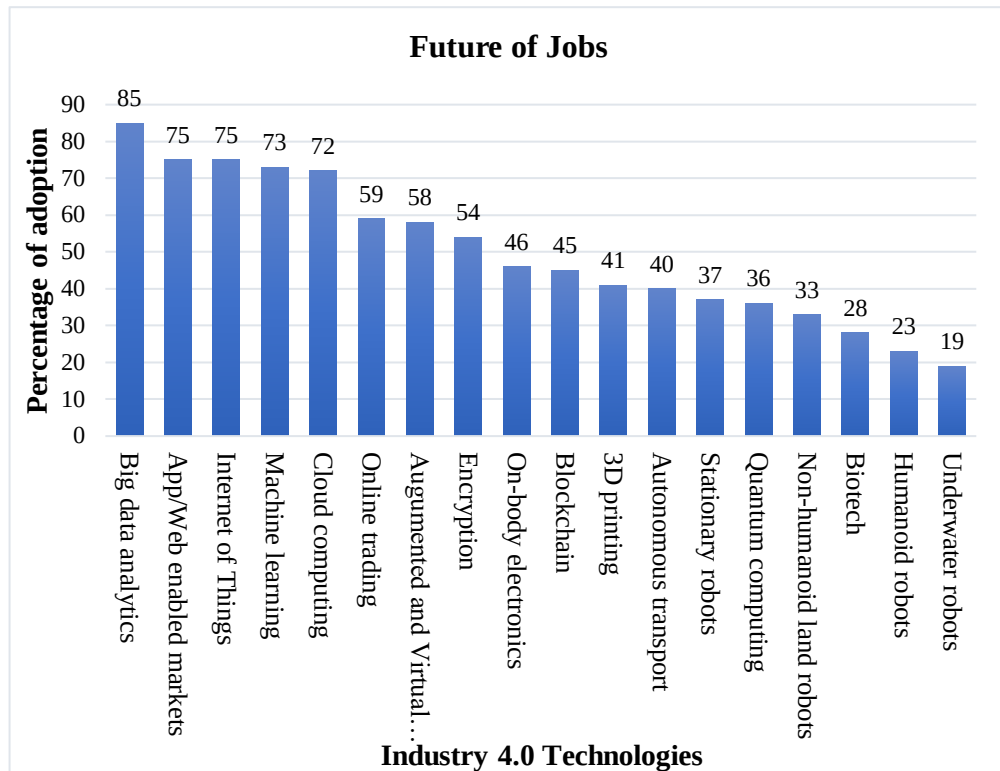


Figure 6: The Future of Jobs in Industry 4.0.

2.2 Engineering and Industry 4.0

There are studies that call for the incorporation of engineering curriculum with components that meet industry needs in this era of Industry 4.0 (Jones, Mardis, & Pahuja, 2019). The Institution of Engineering and Technology (IET, 2016) remarked that

There is deeper concern than in previous years around the skills, knowledge, and experience of the future workforce – postgraduates, graduates, school leavers and apprentices.

CBI (2009) emphasized on students having employable skills and the role of the universities in ensuring this. Royal Academy of Engineering remarked

University engineering courses must provide students with the range of knowledge and innovative problem-solving skills to work effectively in industry as well as motivating students to become engineers on graduation (The Royal Academy of Engineering, 2007).

Table 5: Core Work-Related Skills according to WEF.

Abilities	Basic Skills	Cross-functional Skills
Cognitive Abilities	Content Skills	Social Skills
Cognitive Flexibility Creativity Logical Reasoning Problem Sensitivity Mathematical Reasoning Visualization	Active Learning Oral Expression Reading Comprehension Written Expression ICT Literacy	Coordinating with Others Emotional Intelligence Negotiation Persuasion Service Orientation Training and Teaching Others
Physical Abilities	Process Skills	Systems Skills
Physical Strength Manual Dexterity and Precision	Active Listening Critical Thinking Monitoring Self and Others	Judgement and Decision-making Systems Analysis
		Complex Problem-Solving Skills
		Complex Problem Solving
		Resource Management Skills
		Management of Financial Resources Management of Material Resources People Management Time Management
		Technical Skills
		Equipment Maintenance and Repair Equipment Operation and Control Programming Quality Control Technology and User Experience Design Troubleshooting

There studies on improving skills and expertise in specific engineering disciplines. (Mcmasters, 2004; Delicado, Salado, & Mompó, 2018) in their study discussed some of the steps that should be taken by academia to ensure an adequate supply of competent engineering graduates for the aviation industry. Thornburgh (2014) investigated how product engineers are evaluated for job readiness by potential employees. Ellis (2015) in his study investigated the desired skill features of undergraduate students in civil engineering from the perspective of civil engineering experts. Din Nugraha, Djohar, & Komaro (2019) explored the employability skills that are most appropriate for mechanical engineering graduates in today's era of Industry 4.0.

Also, a number of universities have identified and adopted some teaching and learning strategies to improve the quality of engineering education. National Research Nuclear University, Russia studied the introduction of CDIO (Conceive, Design, Implement, and Operate) approach into the training program to develop the digital electronic skills of specialists in the field of mechatronics and robotics (BaryshevaI, Yudin, Biryukov, Shukina, & Yultyevaa, 2021). Chalmers University, Sweden used a course development initiative using CDIO Standards to increase the knowledge and experience of engineers in applying and integrating optimization theory in engineering design process (Quist, et al., 2017). Jianfeng, et al. (2013) studied the progress made through adoption of CDIO approach in engineering education in the departments of mechanical engineering, electronic engineering, and chemical engineering across universities in China.

Another teaching and learning strategy, Problem-Based Learning (PBL) has been studied in Iowa State University (Mayer, 2013), Delft University of Technology and

Aalborg University (Graaff & Kolmos, 2003; Chen, Kolmos, & Du, 2021). Wang (2016) studied the application PBL to hydraulic engineering education in Taiwan in order to foster problem-solving skills to real-life problems in engineers.

Other approaches that have been studied in engineering education are Research-Based Instructional Strategies (RBIS) particularly in curriculum change and faculty development (Clapp, 2018; Cruz, Hampton, Adams, & Hosseinichimeh, 2019; Waychal, Patil, Deore, & Patil, 2017; Neumeyer, Foote, Beichner, Dancy, & Henderson, 2014; Cutler & Borrego, 2013), Evidence-Based Instructional Strategies (EBIS) in teaching and learning (Krause, et al., 2018; Ankeny, et al., 2018; McEachron, et al., 2010), and Collaborative and Blended learning (Surenderkumar & Priya, 2017).

2.3 Industrial Engineering (IE) and Industry 4.0

According to Institute of Industrial and Systems Engineers

Industrial and systems engineering is concerned with the design, improvement, and installation of integrated systems of people, materials, information, equipment, and energy. It draws upon specialized knowledge and skill in the mathematical, physical, and social sciences together with the principles and methods of engineering analysis and design, to specify, predict, and evaluate the results to be obtained from such systems (IISE, 2021).

In similar interpretation, the department of Industrial Engineering at Eastern Mediterranean University defines Industrial Engineering as

The application of techniques and principles to the improvement, design, and installation of systems that involve people, materials, information, energy, and equipment to provide efficient production of goods and services (EMU, 2021).

Industrial Engineering is a broad field with areas that are intertwined and interconnected to other fields of engineering. EMU identifies Ergonomics, Flexible

Manufacturing Systems, Fuzzy logic and its applications, Linear/convex Feasibility and Optimization, Machine Scheduling, Productivity Measurement, Pull-Push Production Systems, Queuing models, Finance, and Technology Forecasting as areas in this field of engineering. IE is responsible for several aspects of the production chain; integrating processes and practices, people, and information, to produce and supply goods and services. The transformations of the last few years have challenged experts and academics of Industrial Engineering to research new knowledge that meet the rapid changes in consumer market and demands. These changes also affect the training of IE students as there are studies about improving the skills of industrial engineers and enhancing IE education in today's era of Industry 4.0.

This study looks at how the fourth industrial revolution has driven changes in job skills and occupation over the years and the various research carried out for the improvement of engineering education in order to reflect the current realities of the industry 4.0 driven society and workforce. Two surveys for engineering students and engineering industry experts were developed, the students survey provided supplementary data especially about the level of students' knowledge of industry 4.0 technologies to gauge their knowledge of industry 4.0 technologies, while the survey for industry experts and the data collected and analyzed were used to achieve the objectives of this study and provide results on the relevant skills for industrial engineering students for industry 4.0 inspired careers.

The technological transformations of the last few years have challenged experts and academics of Industrial Engineering to research new knowledge that meet the rapid changes in consumer market and demands. These changes also affect the training of industrial engineering students as there are studies about improving the skills of

industrial engineers and enhancing industrial engineering education in today's era of Industry 4.0. While some studies argue that Industrial engineering, despite of being multi-disciplinary should be refined as a discipline with its specific areas of interest identified (Dastkhan & Owlia, 2011), other studies maintain that Industrial Engineering has to be more participatory by incorporating engineering with the humanities, science, and technology (Mendoza-Chacón, Ramírez-Bolaños, Floréz-Obceno, & Díaz-Castro, 2016). Wu, Sodell, Elmustafa, & Haile (2021) developed a course on industry-driven design and manufacturing for manufacturing engineering students at Virginia state University to prepare them for the aerospace industry.

Cristina, Lourdes, & Carlos (2011) used web information of studies done by Spanish universities on industrial engineering degrees to analyze the proposed ideal competencies and match them to the existing syllabus implemented in Spanish universities. They discovered that although required in industry, the new industrial degrees do not reflect competencies as common vision, unrestricted access to knowledge and participation of managers. This study aims to use the multidisciplinary nature of industrial engineering to investigate other relevant technical skills and competences for industrial engineering students to develop for smooth transition into the dynamic industry of today's world, and to become fully grounded professional.

San-Juan, et al. (2015) proposed the use of CATIA V5 software packages to study an object with the purpose of enhancing industrial engineering students' transversal skills. Their method showed an improvement of communication among students, but other transversal skills were not discussed. Jörg, Thilo, & Thomas (2020) created a uniform concept of competence for production technology by carrying out an assessment of conventional descriptions of skills and competencies and compared them to the

competence requirements for production engineering. The result of their study demonstrated that though universal, the definition showed requirements of production engineering.

From Industry 4.0 perspective, (Bilge & Severengiz, 2019) used game-based learning to teach industrial engineering student factory management and complex-problem solving, thus they identified the need to include mechatronics into industrial engineering programs. Other studies also emphasized the industrial engineering curriculum inclusion of divergent thinking Skills (Akcali, Giang, & Landrum, 2020), entrepreneurial mindset skills (Bosman & Duval-Couetil, 2021), verbal and written communication skills (Wagner, 1999; McNair, Forehand, Sutley-Fish, Michael, & Norback, 2004). In these studies, single transversal skill is identified for IE students, however there is a range of transversal skills relevant today in the labor market, this study presents more of these transversal skills that are the relevant requirements for all IE students and not limiting its finding to specific areas of the field.

Sirinterlikci (2020) recommended the inclusion of IoT-based mandatory courses in manufacturing/industrial and mechanical engineering curricula. Jones, Mardis, & Pahuja (2019) studied the alignment between what Advanced Manufacturing (AM) employers in Florida seek and what students should learn in AM programs, they used test mining and Natural Language Processing (NLP) to extract topical words from Job postings and compared them to AM curriculum framework. Salah, Khan, Ramadan, & Gjeldum (2020) used a case study to demonstrate the benefits of integrating the concepts of Industry 4.0 into IE curricula. In this study, recommendations for course contents towards industry 4.0 for the technical skills identified is provided to the department for possible inclusion in IE curriculum for Eastern Mediterranean

University as a first of its kind scholarly contribution in the department of Industrial Engineering.

Table 6: Publications Showing Areas of Career Opportunities for Industrial Engineers.

Topics	Keywords	Publications	Percentage
Process Engineering	Manufacturing Engineering	245	10
	Process engineering	75	
	Systems engineering	649	
	Lean Manufacturing	141	
Cost	Cost	1400	13
	Economic viability	5	
Quality	Quality	1209	13
	Quality Control	183	
	Six Sigma	71	
	FMEA	29	
Logistics and Supply Chain	Logistics	703	17
	Supply Chain	696	
	Transportation	294	
	Storage	255	
Operational Research	Optimization	965	21
	Simulation	1067	
	Multicriteria Decision	35	
	Operational Research	261	

Costa et al. (2021) identified the interrelation between Industry 4.0 and IE. In their review of over 5000 publications on IE and Industry 4.0, they found that high number of publications on specific IE-Industry 4.0 subjects indicated the rising opportunities for Industrial Engineers in industry today (see Table 6).

Chapter 3

RESEARCH METHODS

3.1 Introduction

In this chapter, the methods deployed for this study- the research tools and statistical methods used for the analysis of survey data is done. First, a discussion of the thesis perspective with respect to the research methods and objectives of this study is provided. Then, a synopsis of the research process and a description of the data collection and analysis procedures is completed.

3.2 Thesis Perspective

A major concern for IE students is about how their academic qualifications can help them to secure their dream jobs, however this pursuit usually does not require only academic qualifications but also skills that make these graduates able to perform those jobs. In reality, employers affirm that not just the technical skills, but also professional skills are wanting in job candidates. Studies have shown that there is an uneven inclusion and participation in professional skill development by engineering graduate school despite its importance. So, graduating students are usually faced with the dilemma of how to succeed when they transition into the labor market. To address this issue many employers have made it their responsibilities to train or retrain job-seeking graduates because they typically lack the adequate skill requirements for the job.

In this study, surveys and statistical analysis were used to achieve the purpose of this study by revealing the technical and professional skills that are in-demand in the

industries by employers of IE graduates (Darabi, Harford, Douzali, & Nelson, 2018); Costa, et al., 2021). This research collects the opinions of industry experts and students across the various fields of engineering and related technical sciences. This study concentrates on the technical and professional skills useful for industrial engineers for work in the industry (O*NET, 2021). However, due to the interconnection between industrial engineering and other engineering fields, the data presented in this study can also be applied to other fields.

Common job titles associated with industrial engineering in which graduates can explore are Industrial Production Managers, Logisticians, Operations Research Analysts, Health and Safety Engineers, Human Factors Engineers and Ergonomists, Continuous Improvement Engineer, Operations Engineer, Plant Engineer, Project Engineer, Quality Engineer, Research and Development (R&D) Engineer, Corporate Quality Engineer, Product Quality Engineer, Quality Assurance Engineer, Quality Engineer, Systems Engineer, Reliability Engineer, Supplier Quality Engineer, Validation Specialist, Facility Engineer, Manufacturing Engineer, Plant Engineer, Process Engineer, Process Improvement Engineer, Ergonomics Technical Advisor, Ergonomist, Human Factors Advisor, Human Factors Engineer, Occupational Ergonomist, Industrial Engineering Technologists and Technicians.

In today's world of Industry 4.0, industrial engineers are employed in typical industries as shown in Table 7. In support with the study by Costa, et al. (2021) on the highest areas of opportunities for Industrial engineers, the results of this study will help engineering students to acquire employable skills to have careers in these areas.

Table 7: Largest Percentages of Industrial Engineers Employers.

Largest Employers of Industrial Engineers	Percentage
Transportation equipment manufacturing	18
Computer and electronic product manufacturing	13
Professional, scientific, and technical services	12
Machinery manufacturing	8
Fabricated metal product manufacturing	6

3.3 Sampling Method

Respondents who are IE students were determined by non-random sampling methods; voluntary response sampling was used as respondents agree to partake in the survey. Although the sampling frame included engineering students across all level of education amount to 83 respondents, the actual sampling size were from respondents in industrial engineering across all level of education. For the industry experts, a more direct approach was adopted, cluster sampling where respondents were categorized according to the engineering industry where they work.

3.4 Research Tools and Methods

In recent years, growing numbers of students engaged in educational research have been using surveys as the principal components of their evaluation process. Previously Paper-based surveys that required the physical presence of respondents were widely used, but due to the extremely exhausting nature of getting responses and the cost incurred in using paper surveys, researchers quickly embraced the use of electronic surveys (Miller, Allen, Felder, & Brawner, 2001).

For this study, basic research tools in the form of web/online surveys were used for disbursement and collection of data, the two main tools for broadcasting the surveys

as web links to the respondents are e-mail and Instant Messaging feature on Social Media Platforms. Google Forms, a free and easy-to-develop online survey tool was used to administer the survey of this study to the various categories of respondents. Google Forms also allow automatic presentation and analysis of responses, likewise the integration with Google sheets which makes it easy to download responses as Microsoft Excel Files.

Microsoft Excel is the second major tool used in this research, aside from providing an easy way to clean and organize the surveys responses, Excel also contains statistical tools such as graphs and charts for data analysis and visualization. The process of data extraction with Excel was quite cumbersome due to the fact that the survey questions were in different formats, and there were questions that required multiple answers to a single question. The process of data extraction with Excel was quite cumbersome due to the fact that the survey questions were in different formats, and there were questions that required multiple answers to a single question. With the help of these two research tools, the surveys were low-cost and easily distributed to respondents across different geographical locations, and data were obtained and analyzed easily.

3.4.1 Survey

The survey instruments are shown in the Appendix A and Appendix B to this paper. Two surveys were developed for this research, each of which carry the same title “Questionnaire on the skills required by IE students for a successful career in Industry 4.0”. The target respondents are different, but they have a common demographical characteristic in that they belong to engineering field. The target respondents are industry experts and students across all levels of education. The questionnaire for industry experts has 14 questions while the one for students contains 12 questions. The questions collect information relating to transversal and domain-related competences

which means professional and technical skills respectively. Transversal competences can also be called transferable skills, they are skills that are not only relevant to an individual's current jobs or field of expertise, but all fields of expertise (Oksana, Galstyan-Sargsyan, López-Jiménez, & Pérez-Sánchez, 2020). Question 5 and question 6 of the Appendices A and B respectively contains questions that test the respondents' level of proficiency in transversal skills, the other questions are domain-specific with some exception that aims to collect demographical information (see Appendices A and B).

The surveys in this study have been adopted from the ERASMUS+ CBHE PROJECT on "Curriculum Development of master's degree Program in Industrial Engineering for Thailand Sustainable Smart Industry -MSIE4.0"; Project Number: 586137-EPP-1-2017-1-TH-EPPKA2-CBHE-JP. This was a combined capacity-building project between nine universities, six in Thailand and three EU partners with the purpose of improving the capability of universities in Thailand to provide high quality competence-based program that aligns with sustainable smart industry for IE master students and conforms to (EQF) European Qualifications Framework (Prince Of Songkla University, 2017). Other literatures were also studied with the aim of investigating what graduates are doing in their respective workplaces, what tools they find most important for their jobs, their socio-demographic background, career issues, the needs of employers and the efforts of relevant stakeholders in addressing the demands for Industry 4.0 skills (Finn & Cole, 1998; Cole & Tapper, 1998; Paul et al., 2019; Rohde & Godwin, 2019; Tyson, Barger, & Jayaram, 2019; Kelceoglu & Kutuk, 2020 and Perez-Felkner et al. 2020). However, industry experts' opinion collected from the survey is the major determinant of the identified skills, other occupational

website resources referenced in this paper served supplementary and expository purposes.

The survey questions were designed in such a way that they test the respondents' knowledge of the transversal and industry-specific skills, while also evaluating their level of competencies in these skills. Care was taken to ensure that the questions were relatable and not time-consuming in order to maintain continual interest of the respondents. Both questionnaires have a blend of the following question types (See Figure 7-11):

- Demography questions
- Rating Scale questions
- Multiple-choice question with single answer selection
- Matrix questions
- Multiple-choice questions with multiple answers selection

2. What is your current level of education? *

1. Undergraduate

2. Postgraduate

3. Doctoral

Figure 7: A Sample of Demography Question from the Survey

5. On a scale of 1 to 5, describe the level of relevance of your coursework to Industry 4.0?

	1	2	3	4	5	
Not relevant	☐	☐	☐	☐	☐	Highly relevant

Figure 8: A Sample of Rating Scale Question from the Survey

14. How did you acquire your I4.0 skills and expertise? *

- ☐ Undergraduate school
- ☐ Graduate school
- ☐ Work training/coaching/seminar
- ☐ Self-funded training outside school/work

Figure 9: A Sample of Multiple-Choice Questions with Single Answer Selection

8. Which of the following areas relating to Industry 4.0 do you think there would be greatest advancement in the next three years? (Can answer more than 1)

- ☐ Advance Robotics
- ☐ Addictive manufacturing
- ☐ Augmented reality
- ☐ Simulation
- ☐ Horizontal and vertical integration
- ☐ Cloud Computing
- ☐ Cybersecurity

Figure 10: A Sample of Multiple-Choice Questions with Multiple Answers Selection

	None	Small	Medium	High	Very High
Cognitive Flexi...	☐	☐	☐	☐	☐
Creativity	☐	☐	☐	☐	☐
Logical Reason...	☐	☐	☐	☐	☐

Figure 11: A Sample of Matrix Questions from the Survey

3.4.2 Excel Tools

The responses of the survey were downloaded from Google forms to Google sheets where simple data analysis can be performed. However, for this study, the responses were exported to Microsoft excel for offline access and more data analysis tools, also to deploy advance graphical tools to present the results and aid discussion. Majority of the survey results are presented in graphs and charts to visually represent the data and demonstrate the relationships between them. This choice is influenced by the objectives of the study and the types of data collected from the survey which were mainly nominal and ordinal data types.

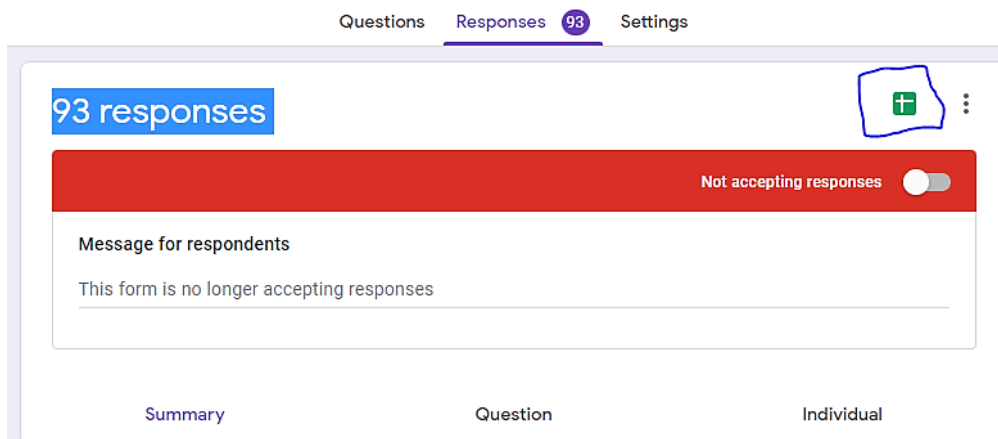


Figure 12: Survey Response Download to Google Sheets

Prior to this, the raw survey responses were cleaned and organized with the use of the pivot table function in Microsoft Excel, after which the appropriate charts and graphs were used to display summaries and results from the data set.

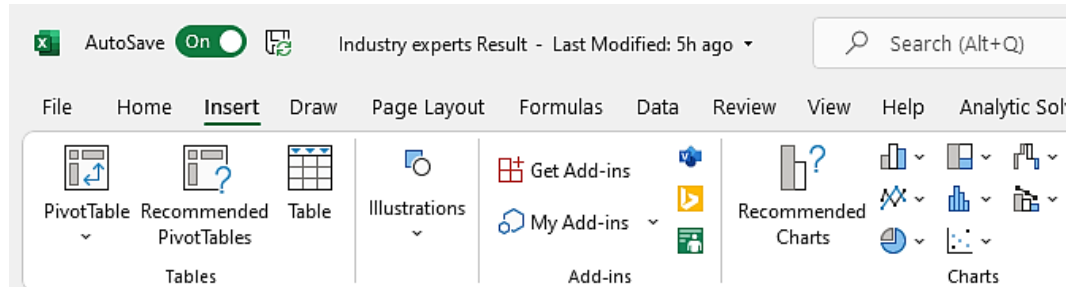


Figure 13: Data Presentation Tools Used in the Study

Table 8 shows the graphical tools used for presentation of the survey response according to the data types illustrated by the Industry Experts survey questions (see Appendix A).

Table 8: Example of Data Presentation Tools and Data Types for the Questionnaire

Survey Question	Data Type	Tools used
1, 8, 11	Nominal/Discrete	Clustered Column
2 and 7	Ordinal/Discrete	Data Table & Stacked Bar
3, 9 and 13	Ordinal/Discrete	Stacked Column
4, 5, 12	Ordinal/Discrete	Stacked Bar
10	Nominal/Discrete	Stacked Bar
6	Nominal/Discrete	Data Table & Stacked Column

Chapter 4

QUESTIONNAIRES

4.1 Introduction

The use of surveys is widely established as an effective method of obtaining research data. Academic, companies, and political organization often adopts questionnaires to carry out surveys. Web-based or online questionnaires is an excellent way to quickly administer surveys and collect research data. This chapter covers the process of developing the questionnaires for this study. Each of the questionnaires contained a section that explains the aims of the study, a section that confirms that the respondents voluntarily agree to participate in the survey, and a section that contained the questions. E-mail addresses of the respondents were collected as a show of acceptance of voluntary participation and requisite age. Survey responses provide collective evaluation and opinions of the respondents. The end results of the survey responses provided quality assessment of Industry 4.0 technologies and skills that are required to produce competent engineering graduates for the rapidly changing labor market.

4.2 Survey Preparation and Execution

The first step in developing the survey was to investigate the technology skills, tools, knowledge, and professional skills that are desired in engineering industries. For the investigation, the Occupational Outlook Handbook (U.S. Department of Labor, 2021), the Occupational Information Network (O*NET, 2021), and the Future of Jobs Report were sources of relevant materials for this survey. Then, the survey questions were

developed with Google form, the responses of each respondent are aimed at determining the respondent's:

- Knowledge of Industry 4.0 and their level of expertise in the different aspects of Industry 4.0.
- Level of expertise in professional skills which are applicable to their jobs and coursework.
- Competence level in technical skills associated to Industry 4.0 in their workplace and classes.
- Proficiency in the use of software application utilized in their Industry 4.0 workplace and classes, laboratory, or practical sessions.
- Medium through which they acquired their expertise of Industry 4.0.

Questions Responses 93 Settings

Section 1 of 2

Questionnaire on the skills required by Engineering students for a successful career in Industry 4.0.

Thank you very much for participating in this study with the titled, Assessment of the technical skill requirements for industrial engineering students towards a career in Industry4.0. This study is being conducted by Toluwalase Opanuga under the supervision of Assoc. Prof. Dr. Hüseyin Güden. It aims to collect the professional opinions of industry experts on the skills required by future engineers who are presently students for a successful career in industry 4.0. The study should take no more than five minutes to complete.

Of course, you are not obliged to participate in this study and are free to refuse to participate. You may also withdraw from the study at any point without giving any reason. In this case, all of your responses will be destroyed and omitted from the research. If you agree to participate in and complete the study, all responses and questionnaires will be treated confidentially. Your email and identifying information will be kept securely and separately from the rest of your questionnaire. Data will be stored for a maximum of six years after the study. Once the data is analyzed, a report of the findings may be submitted for publication.

The study should take no more than five minutes to complete. If during the completion of this questionnaire you have questions or contributions, please contact the researcher Toluwalase Opanuga via email on Toluwalase.opanuga@outlook.com.

Figure 14: Questionnaire Introduction Showing Instructions to Respondents.

Once the survey was developed and the relevant approvals were granted, the next action was the disbursement of the survey link to the target participants via:

- Bulk email broadcast to alumni of the department of Industrial Engineering.
- Customized emails to engineering employers and employees soliciting for participation in the survey.
- Personal contacting of prospective participants via social media, educational and professional platforms such as LinkedIn and ResearchGate.
- Bulk email broadcast to students.
- Personalized emails.
- Contact with participants via social media, and
- One-on-one/physical contact.

Lastly, the responses were downloaded as an excel file, cleaned, and analyzed using excel pivot tools.

To signify your voluntary participation, Please tick the boxes to confirm that you agree to each statement. *

- ☐ I confirm that I have read and understood the information sheet for this study and have had the opportunity to ask any questions.
- ☐ I understand that my participation is voluntary and that I may withdraw from the study at any time without explanation.
- ☐ I agree to take part in this study.

Figure 15: Questionnaire Introduction Showing Consent Confirmation

4.2.1 Questionnaire for Industry Experts

The purpose of this questionnaire is to get the professional opinions of industry experts about the skills required by future engineers for careers in industry 4.0. For this study, Industry experts are current employers and employees of companies in various fields

of engineering. These people have educational backgrounds in engineering and considerable knowledge of the current industrial practices and skill requirements in their chosen field of work. With an anticipated participation of 100 industry experts, 93 responses were collected.

4.2.2 Questionnaire for Engineering Students

This questionnaire's aim is to evaluate the knowledge of engineering students in aspects of Industry 4.0. The varying level of knowledge that is indicated by the student's responses will serve as a tool in drawing a conclusion and recommendation from this study. The population target for this survey are students from the undergraduate, graduate, and doctoral levels of education.

In total, as shown in Figure 16, the survey consists of 82 responses to the questionnaire in Appendix B.

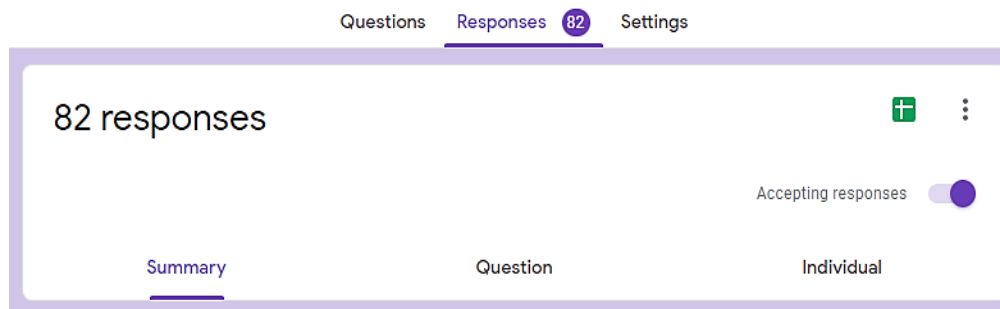


Figure 16: Total Number of Students' Survey Responses

4.3 Evaluating Survey Responses

The process of evaluating the respondents' answers in order to achieve the aims of this study was done using excel. Though Google Forms collects the data and expresses it as charts and graphs, it is impossible to download these charts and graphs format. So, the responses were extracted as Google Sheets and then downloaded to Microsoft

Excel, after which the raw data are cleaned, organized, and analyzed using pivot tools before they were presented as charts or graphs.

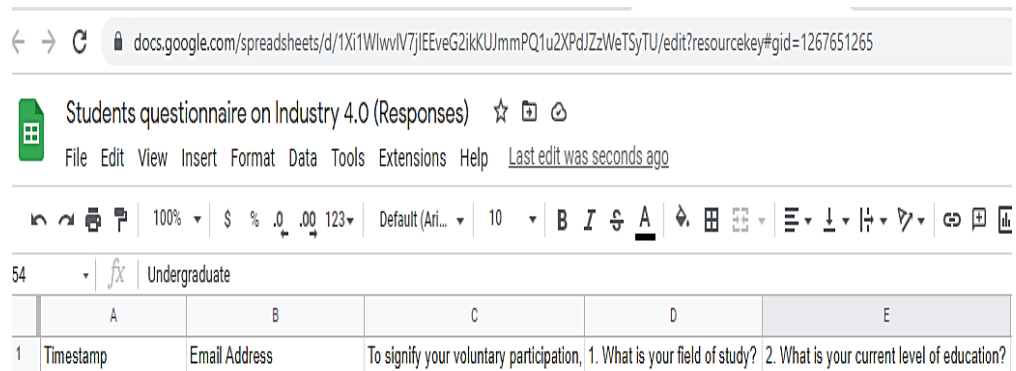


Figure 17: Google Spreadsheets Sample of Survey Responses

Chapter 5

RESULTS AND DISCUSSIONS

5.1 Introduction

In this chapter, firstly, each survey question is presented, subsequently the results collected are shown and discussed; since the data type gathered from the survey are nominal and ordinal data types, these results are presented against the population of respondents.

5.2 Results for Engineering Students

The respondents answered specific questions related to their field and level of study, their knowledge of Industry 4.0 and the usage of Industry 4.0 technologies for their coursework. These and other questions are discussed in this section.

5.2.1 Question 1: What is Your Field of Study?

This question collects data on the students' field of study. Responses show that majority of the students are from Industrial Engineering, taking up 41% of the total respondents. As seen in Figure 18, there is a record from social work, this will be discarded in all analysis since it is not an engineering field. There are two records of applied mathematics and statistics, these will be considered in further analysis since both fields are integral part of engineering. Due to little percentage contributions of the other fields of study to this survey, the holistic results be discussed as for Industrial Engineering.

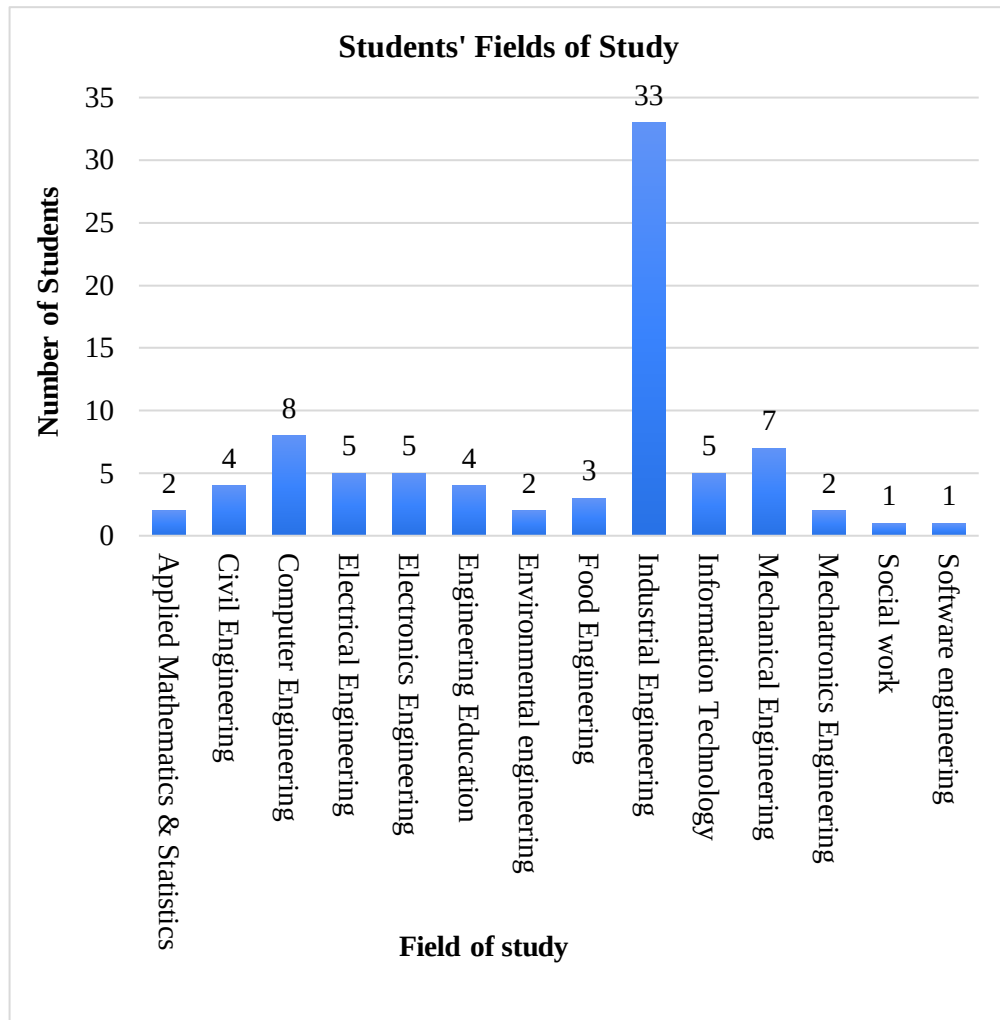


Figure 18: Number of Students according to their Field of Study

5.2.2 Question 2: What is Your Current Level of Education?

The responses to this question in Table 9 shows that equal number of undergraduate and post-graduate students participated in the survey, this amounts to 77%, while the remaining respondents are doctoral students.

Table 9: Number of Students according to their Current Level of Education

Level of Education	Doctoral	Postgraduate	Undergraduate
Total	19	31	31
Percentage	24	38	38

5.2.3 Question 3: Do You Know About Industry 4.0?

The responses to this question as displayed in Figure 19 shows an inverse relationship between number of students and their knowledge of Industry 4.0. This is more pronounced amongst undergraduates. On the overall, 63% of students have knowledge of Industry 4.0, however, out of this, only 21% have applicable knowledge of the concepts of Industry 4.0 and they are mostly postgraduate students.

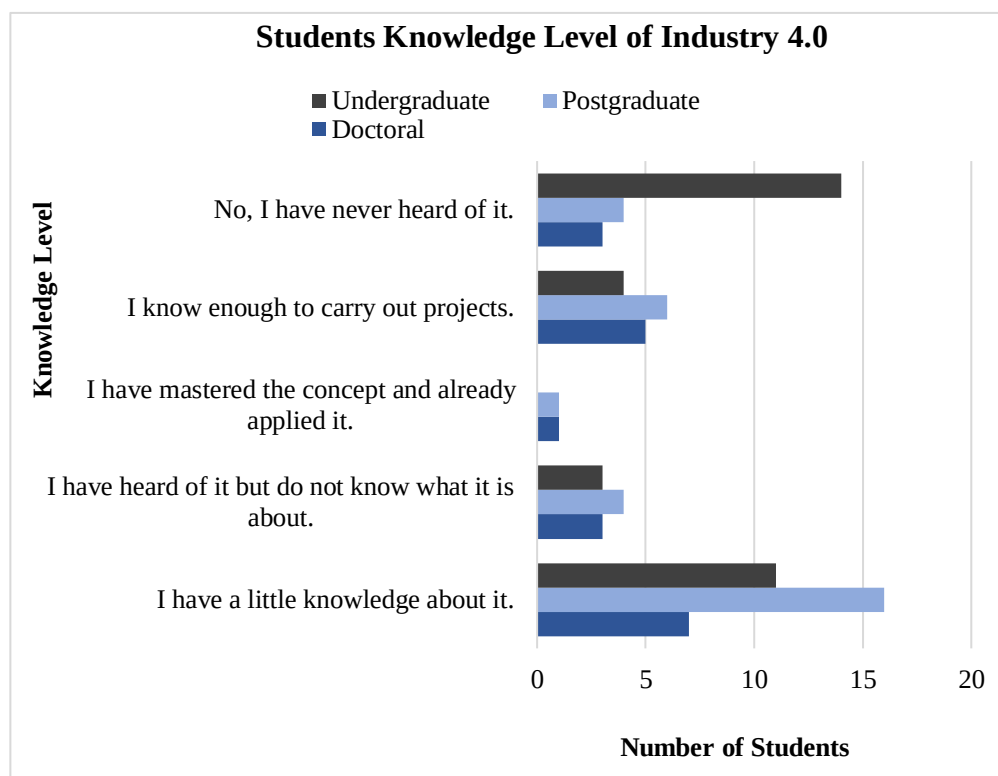


Figure 19: Students' Level of Knowledge of Industry 4.0

This suggests students' high level on awareness of Industry 4.0, especially amongst undergraduates. However, more effort should go into exposing students to the concepts of Industry 4.0 and developing their interest through practice-based and problem-based pedagogical approaches.

5.2.4 Question 4: What is Level of Your Knowledge/Expertise in the following Aspects of Industry 4.0?

The responses to this question as displayed in Figure 20 shows that despite the high number of none-to-small expertise in all aspects, students still show high knowledge of IoT, Big Data and Analytics and Simulation.

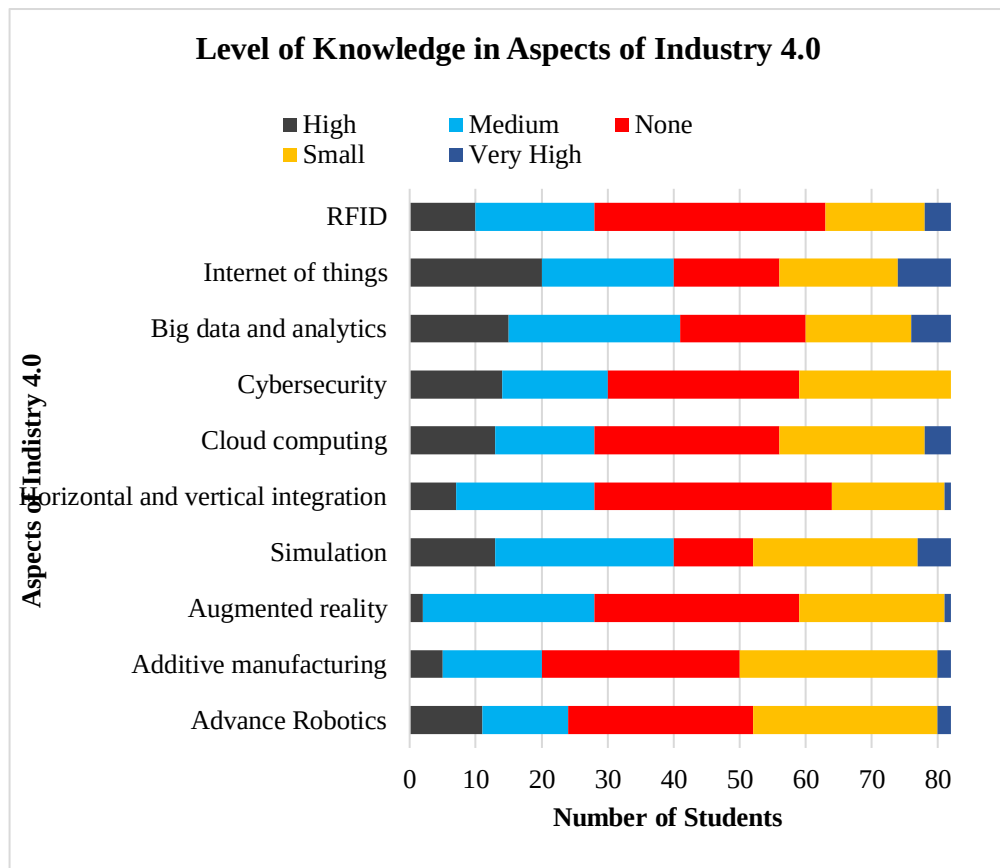


Figure 20: Students' Level of Knowledge in Aspects of Industry 4.0

5.2.5 Question 5: On a Scale of 1 to 5, Describe the Level of Relevance of Your Coursework to Industry 4.0?

Overall students' responses show that their coursework is of high relevance to learning aspects of Industry 4.0 and the acquisition of relevant skills in these aspects (see Figure

21). However, the results also suggest that there is need to increase awareness of Industry 4.0 amongst students.

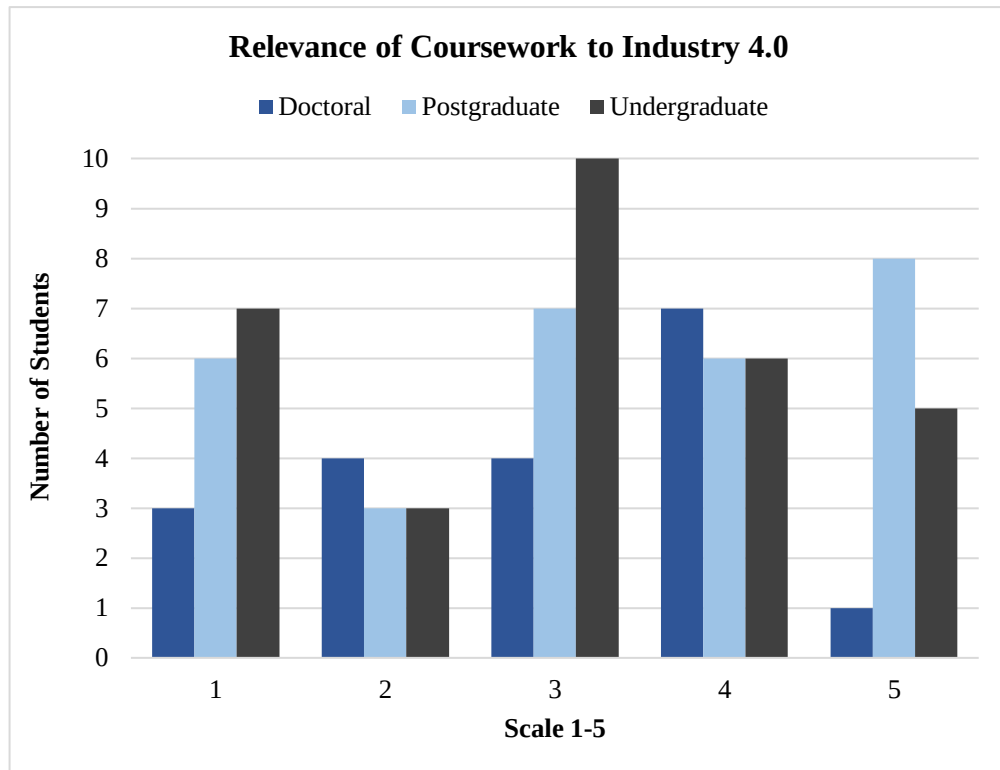


Figure 21: Relevance of Students' Coursework to Industry 4.0

5.2.6 Question 6: With Respect to Industry 4.0, Rate Your Competence Level in the following Skills?

The results as depicted in Figure 22 show that the number of IE students with no competence is very small and progresses with level of competence. This suggests that student's coursework, internship, and laboratory activities may have substantially helped in professional skills acquisition and application. With the great deal of importance placed on these skills in the labor market, the respondents have shown that they have considerable competence in relevant transversal skills. However, effort should be made to help students learn skills in Troubleshooting and ICT Literacy

through pedagogical approaches such as Problem-Based Learning and Project Based Learning.

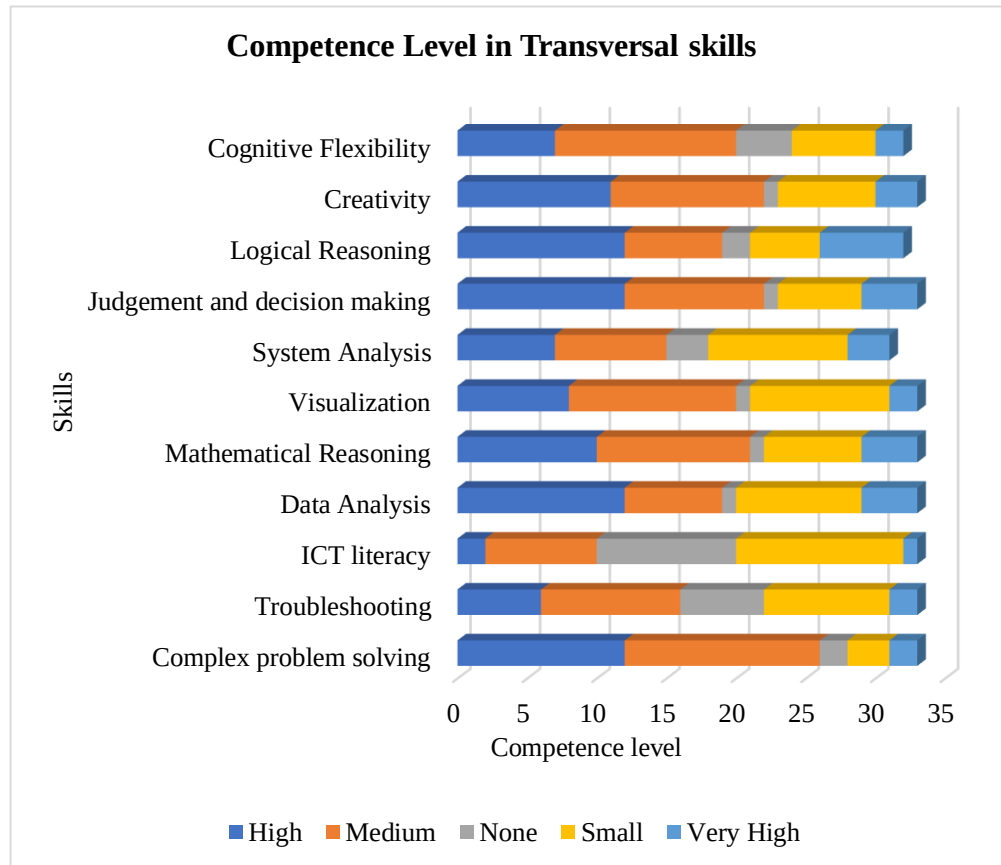


Figure 22: IE Students' Competence Level in Transversal Skills

5.2.7 Question 7: What Tools/Technologies Do You Presently Use to Access and Analyze Data in Your Coursework?

Students' responses show high use of Desktop productivity and Data Visualization tools, the responses are similar to the responses of Industry experts. Big Data Analytics. is a crucial aspect of Industry 4.0, the results shown Figure 23 suggest that students should be encouraged to do more of data analysis through assignments and projects.

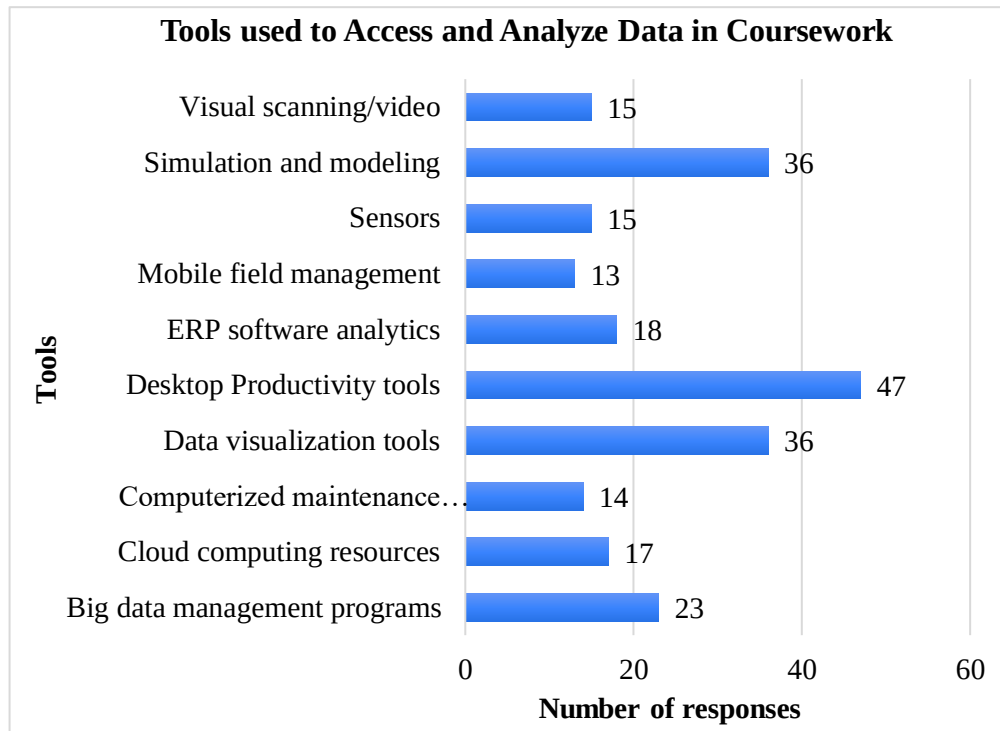


Figure 23: Technologies Students Use to Access and Analyze Data in their Coursework

5.2.8 Question 8: By How Much Do You Think There Will Be an Advancement in Industry 4.0 Related Technologies in the Next Three Year?

85% of respondents think that there will be advancements in Industry 4.0 technologies over the next three years (see Figure 24). This agree with the response of 87% of Industry Experts, this suggests that engineering education in universities should mirror the technological and skill changes that are expected in the future.

5.2.9 Question 9: Which of the following Industry 4.0 Areas Do You Envisage a Great Advancement in the Next Three Years? (Can Answer More Than 1)

Responses from students suggests that Advance Robotics, IoT, Cloud Computing, Big Data and Analytics are the areas of highest advancement over the next three years (see Figure 25). Comparing this result to that from industry experts, there is a difference, in that Advance Robotics is rated lower in the later. Regardless, the results in both

support the need for engineering education to place emphasis on learning Big Data and Analytics, IoT, Cybersecurity and Cloud Computing.

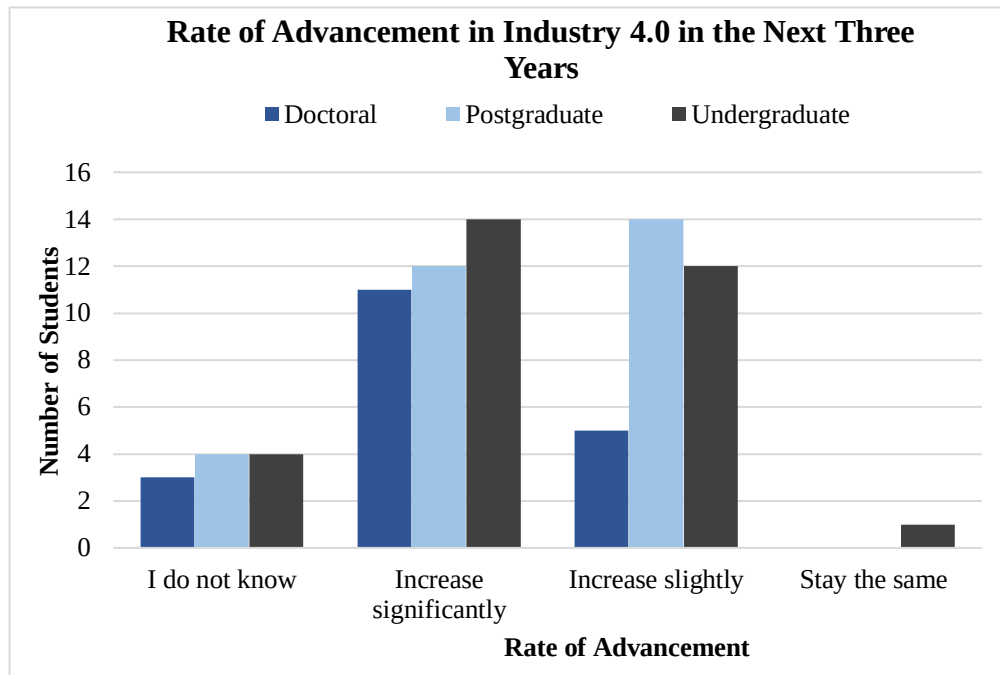


Figure 24: Rate of Advancement in Industry 4.0 Technologies in the Next Three Years

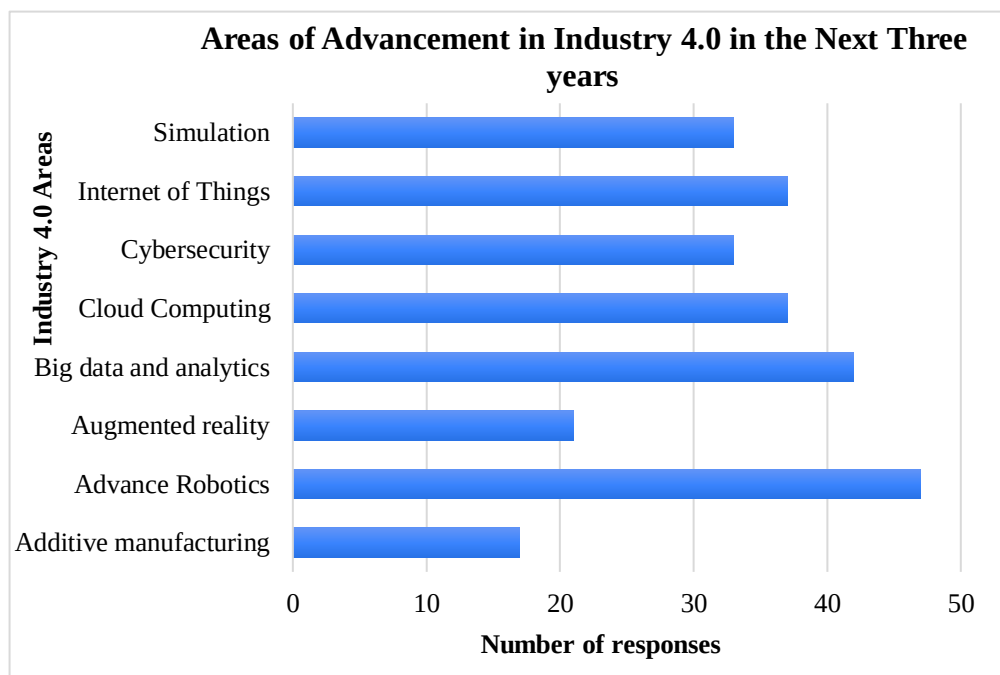


Figure 25: Industry 4.0 Areas Where Great Advancement is Envisaged

5.2.10 Question 10: From the Aspect Of Industry 4.0, Select Your Level of Competence in the following Software/ Technical Skills?

Compared to professional skills, the results displayed in Figure 26 suggest that high number of students possess small to no competence in all the technical skills indicated, though high competence in Operations management and Big Data Analytics is observed. This overall skill deficit in students is also observed in industry experts, but in a lower number. So, there is need for need for academia to help student to build high competence in these technical skills for careers in Industry 4.0.

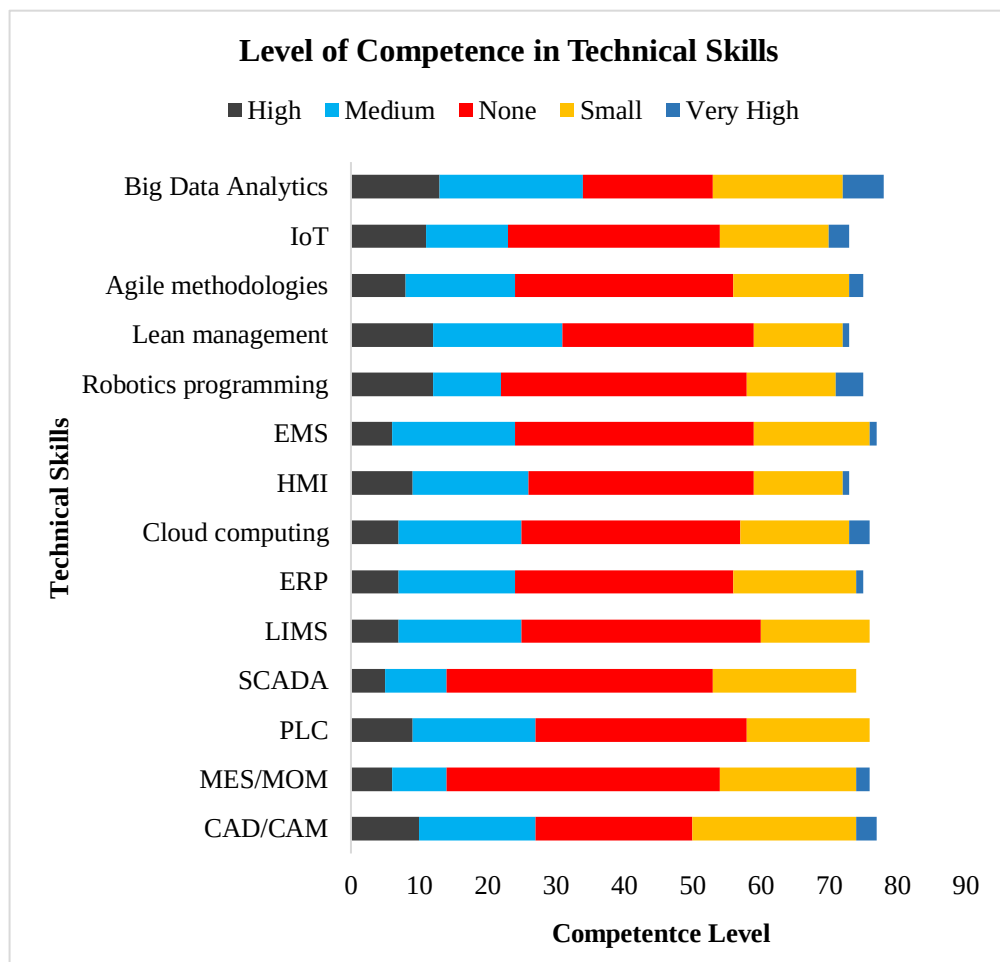


Figure 26: Respondents' Level of Competence in Technical Skills

5.2.11 Question 11: According to Level of Importance, Select Which Software/ Technical Skills are Relevant for IE Students to Learn for a Career in Industry 4.0

The highest overall response to this question lies in Average, this might suggest majority of the students were being modest with their responses. However, it can be observed that Big Data Analytics, IoT and Human-Machine Interface were assessed more to be of very high importance, while Operations Management, Machine coding, EMS and Cloud computing were assessed more to be of high importance. All these skills are relevant for IE students to learn but focus can be placed on the mentioned skills (see Figure 27).

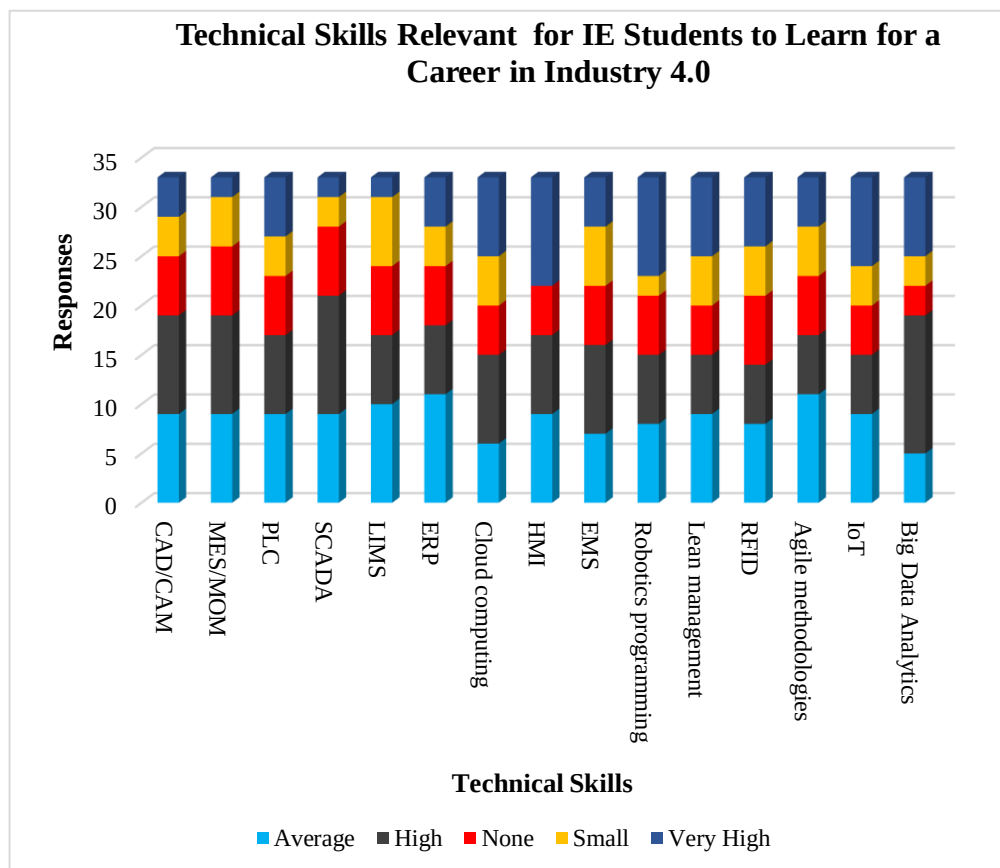


Figure 27: Technical Skills Relevant for Students to Learn for a Career in Industry 4.0

5.2.12 Question 12: How Did You Acquire or Intend to Acquire Your Industry 4.0 Skills/Expertise?

The responses to this question displayed in Figure 28 suggest that 12% of students acquired or intend to acquire Industry 4.0 skills from undergraduate school. 23% of the respondent relied or will rely on personal training while 38% acquired or intend to acquire these skills from work trainings. It can be observed that undergraduate students tend to rely more on outside school methods in order to gain knowledge on Industry 4.0 concepts, this might suggest a lack of confidence in the ability of the university system to provide the requisite work skills. Hence there is need to put effort in building their confidence.

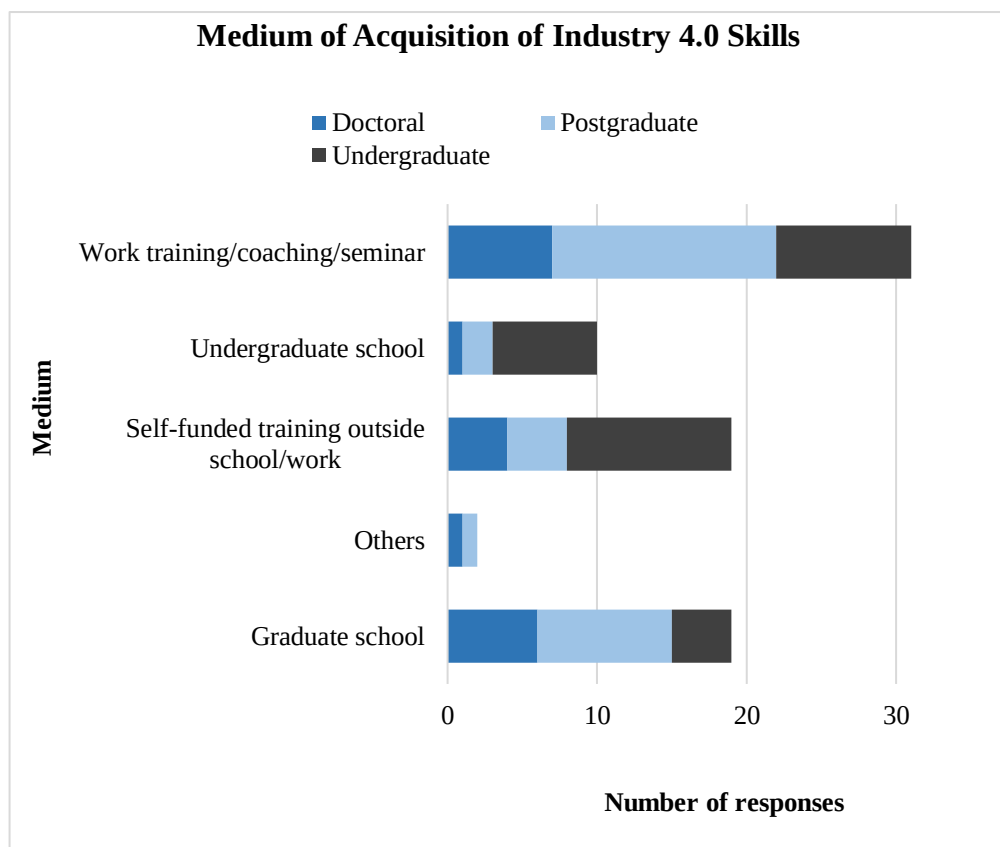


Figure 28: Ways in Which Students Acquired or Intend to Acquire Industry 4.0 Skills.

5.3 Survey Results for Industry Experts

The respondents answered specific questions related to their primary industry, their knowledge of Industry 4.0, usage of its technologies for their jobs and other questions that will be discussed in this section. The results demonstrate experiential opinions of current employers and employees of engineering companies.

5.3.1 Question 1: What is Your Industry/Field?

In cleaning up the data, some categories are collapsed into one - Clothing/Apparel/Textile, packaging, Food/Beverage Processing, chemical products, FMCG - Home appliances and Industrial Engineering are categorized under Manufacturing; Automotive and Robotics are classified under Control/Automation; Metal work and Machining categorized as Mechanical. The responses to this question show the areas in which the 93 respondents currently work. 12 industries were identified as shown in Figure 29 depicting that majority of the respondents belong to Manufacturing, IT, and Electrical.

5.3.2 Question 2: Do You Know about Industry 4.0 Concept?

In response to this question, Table 10 shows that though 67% of the respondents have knowledge about Industry 4.0, 39% of them, which is more than half do not have applicable knowledge of the concept, and the respondents with no knowledge of Industry 4.0 make up 34% of the total population. This suggests a poor awareness of Industry 4.0 concepts in the engineering labor market. Upon further analysis, according to the industry field, the highest number of respondents that have no knowledge of Industry 4.0 concepts are in Electrical sector.

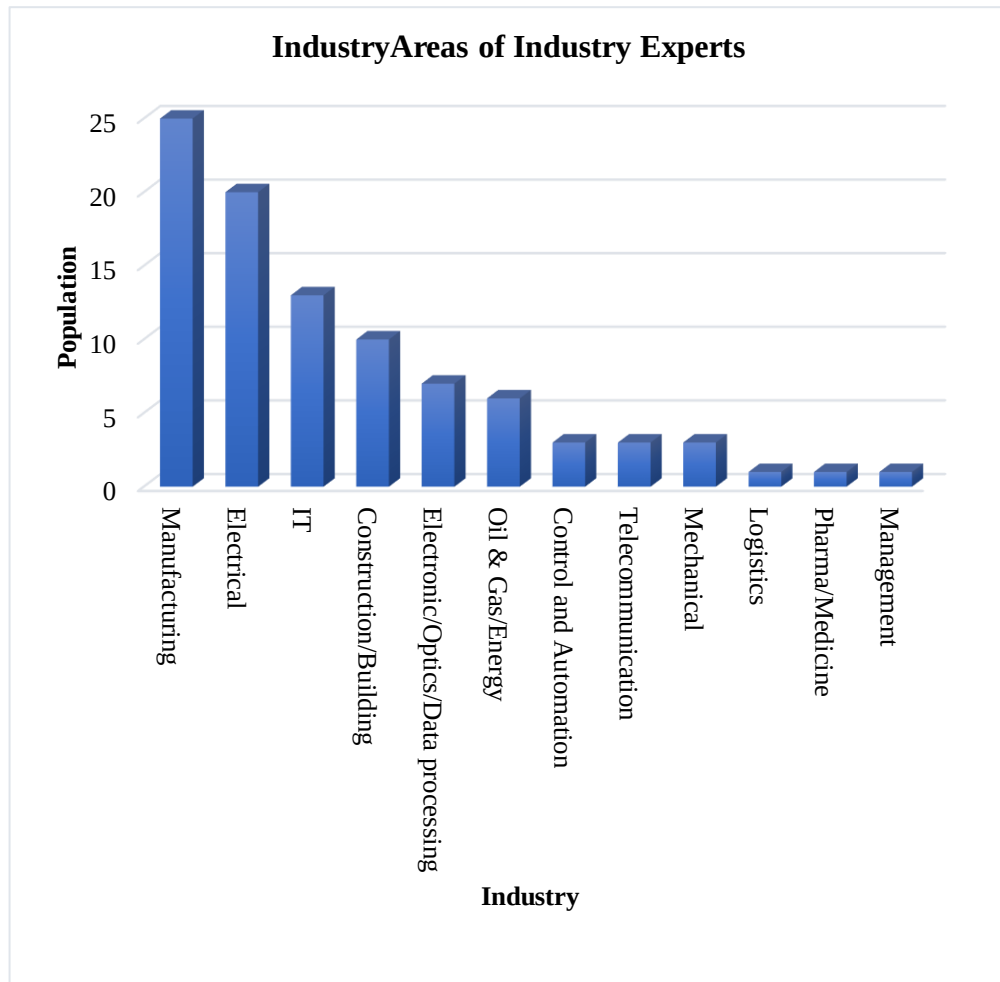


Figure 29: Industry Type of Experts with Population Count.

Table 10: Level of the Knowledge of Industry 4.0 for 93 Industry Experts

Level of Knowledge of Industry 4.0	Population	Percentage
I have a little knowledge about it.	36	39
I have heard of it but do not know what it is about.	9	10
I have mastered the concept and already applied it.	2	2
I know enough to carry out projects.	24	26
No, I have never heard of it.	22	24
Total	93	100

5.3.3 Question 3: What is Level of Your Knowledge/Expertise in the following Aspects of Industry 4.0?

This question breaks down the level of expertise of the respondents in each concept of Industry 4.0. Figure 30 shows that high number of respondents either have no expertise or small expertise in all the identified Industry 4.0 skills, and observation is highly pronounced in Horizontal and Vertical Integration. The figure also show that high number of respondents have applicable expertise in Big Data and Analytics and Internet of Things which suggests the importance of these areas to their jobs.

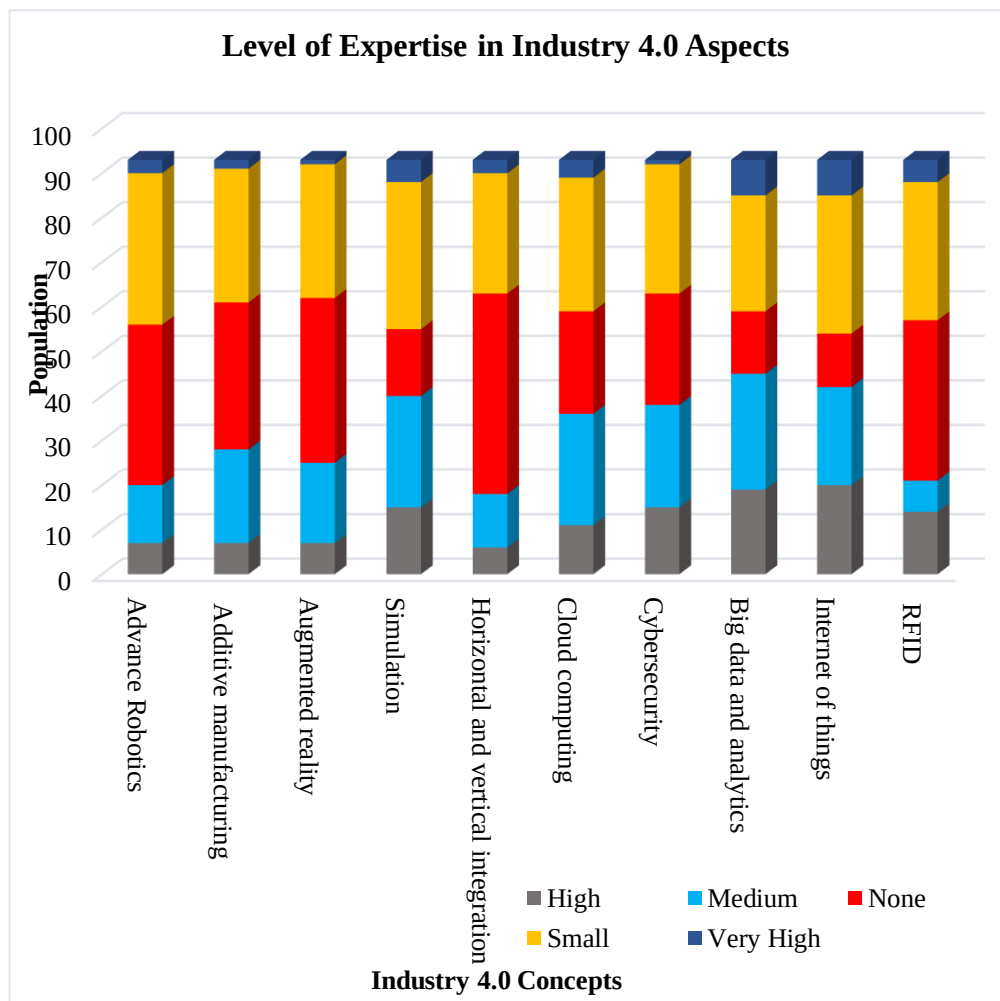


Figure 30: Level of Knowledge of Industry 4.0 according to Experts' Field.

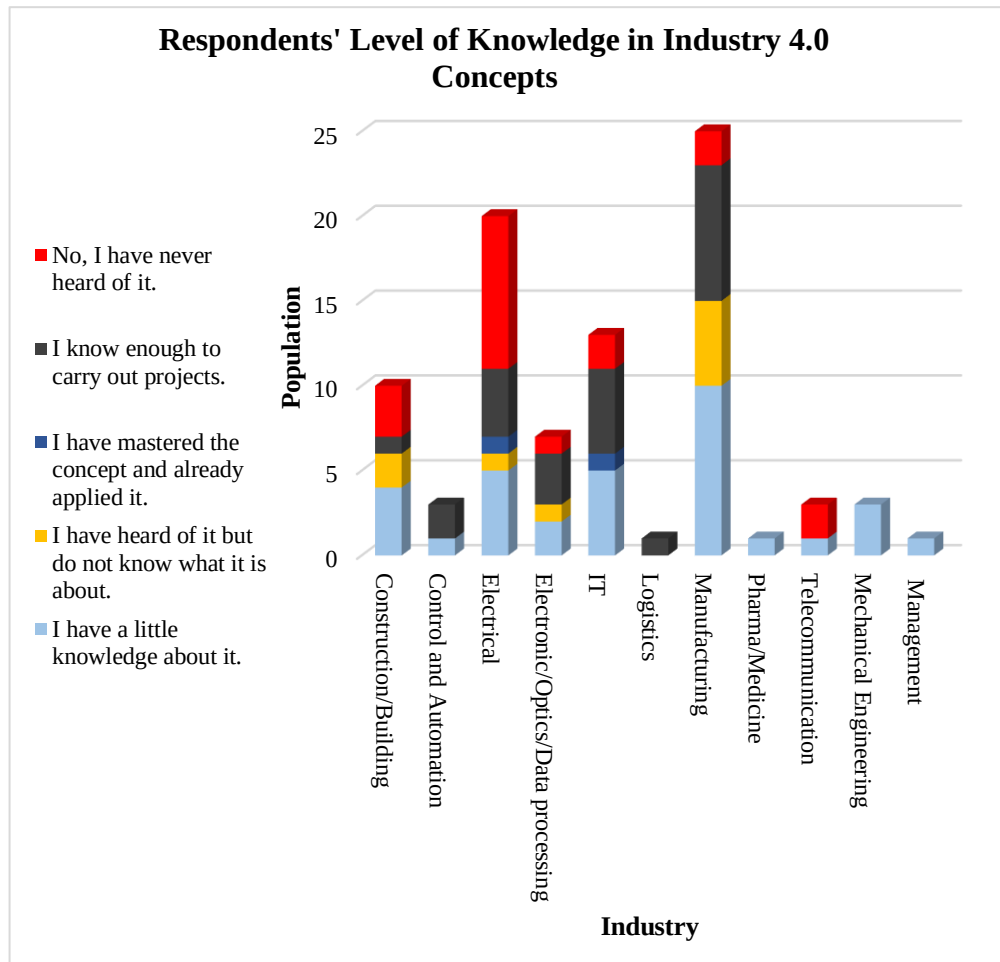


Figure 31: Experts' Level of Expertise of Industry 4.0 Aspects.

5.3.4 Question 4: What is the Level of Relevance of Industry 4.0 to Your Field Today?

The response to this question is measured on a scale of 1 to 5 with 1 representing 'Not relevant' and 5 denoting 'Highly relevant'. Figure 32 shows no record for scale 0 which implies that no respondent think that Industry 4.0 is irrelevant to their field. Majority of the respondents choose scale 4 and 5 indicating that Industry 4.0 is highly relevant to their various industries.

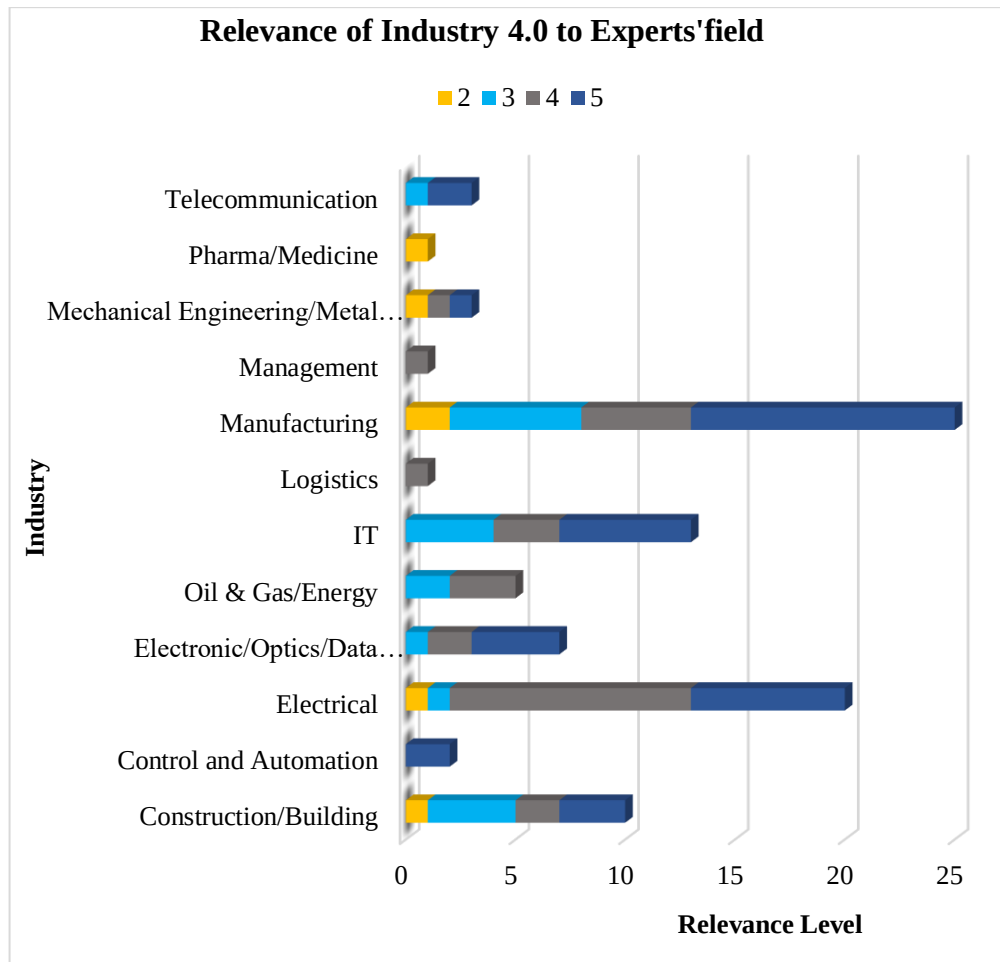


Figure 32: Extent of the Relevance of Industry 4.0 To Respondents' Fields.

5.3.5 Question 5: Rate Your Level of Knowledge in the following Skills Relevant to Industry 4.0?

This question evaluates respondents' proficiency level in a list of professional skills that are relevant in Industry 4.0. Figure 33 depicts that on the overall, respondent possess very high knowledge level in Mathematical Reasoning, Judgement and Decision making and Complex Problem Solving even though applicable level of knowledge is observed across all the identified skills suggesting that all the skills are of high relevance to a career in Industry 4.0. The low number of respondents with no expertise in Logical Reasoning, Mathematical Reasoning and Complex Problem Solving further support the relevance of these skills. jobs.

5.3.6 Question 6: What Tools/Technologies Do You Presently Use to Access, Analyze, and Leverage Data in Your Industry?

A lot of technologies are currently used in the industry for collecting, recovering, and manipulating data in order to make pertinent business decisions, this question evaluate what technologies are prominently used in the respondents' field of work, Table 11 reveals that Desktop Productivity, Data Visualization, Simulation and Modeling and Process Automation tools are prominent and useful across all industries.

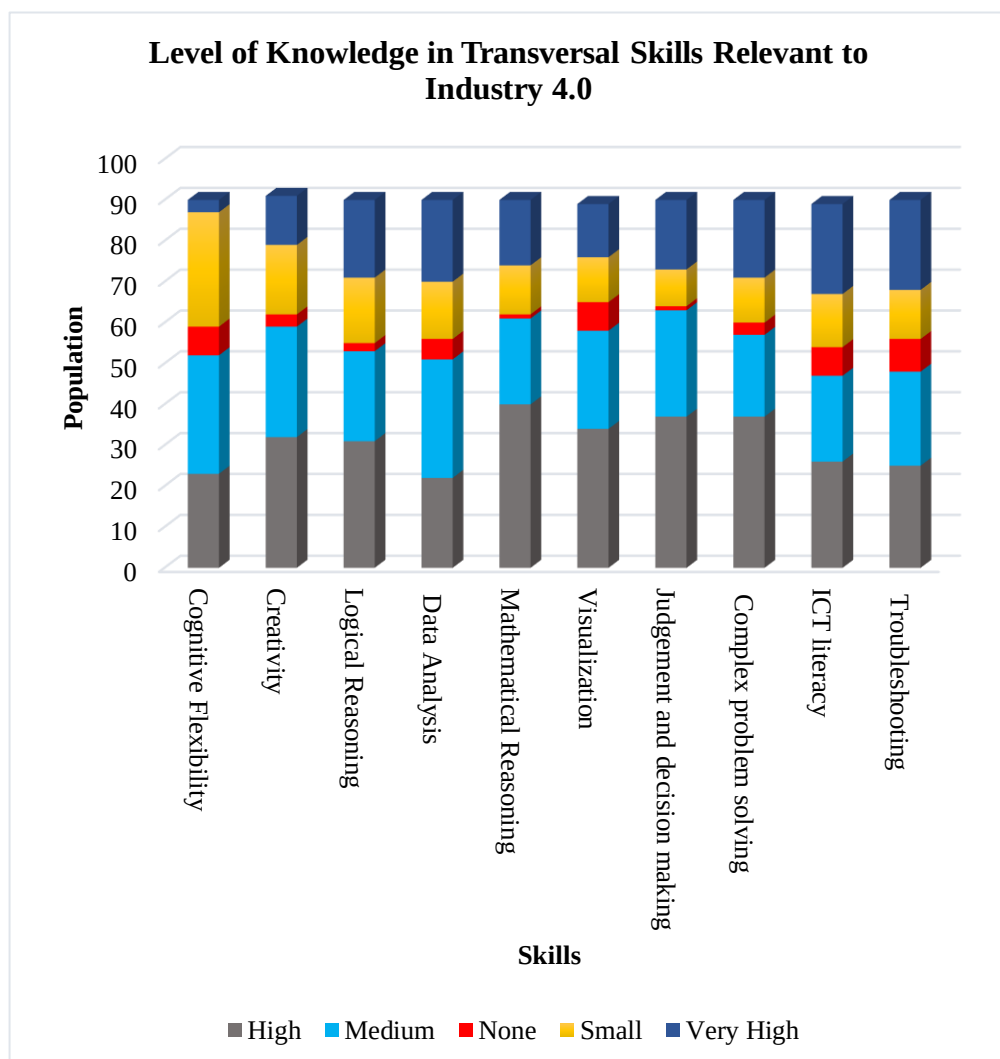


Figure 33: Industry Experts' Level of Knowledge in Skills Relevant to Industry 4.0

Table 11: Tools Used by Respondents to Access, Analyze, and Leverage Data

Tools/Technologies	Population
Robotics	11
Mobile Field Management	15
Visual Scanning/Video	16
Cloud Computing Resources	31
Computerized Maintenance Management System (CMM)	29
Sensors	35
ERP Software Analytics	37
Process Automation	38
Big Data Management Programs	32
Simulation And Modeling	39
Data Visualization Tools	55
Desktop Productivity Tools	54

5.3.7 Question 7: How Much Do You Anticipate an Advancement in Industry 4.0 Technologies in the Next Three Year?

With high response supporting a significant increase in the advancement of Industry 4.0, the need for engineering students to acquire the industry skills that aligns with this rapidly changing world of technology is expedient.

Table 12: Anticipated Advancement in Industry 4.0 Technologies in the Next Three Years

Anticipated advancement in Industry 4.0	Total	Percentage
I Do Not Know	9	10
Increase Significantly	54	59
Increase Slightly	26	28

Stay the Same	3	3
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5.3.8 Question 8: Which of the following Areas Relating to Industry 4.0 Do You Think There Would Be Greatest Advancement in the Next Three Years? (Can Answer More Than 1)

This question collects opinions on the areas where the greatest advancement in Industry 4.0 is likely to occur. Figure 34 depicts that these advancements are majorly in Internet of Things, Big Data and Analytics, Cybersecurity and Cloud Computing. With this revelation, there arise the need for academia to begin to include development of skills in these area as part of the objectives of courses taught in universities in order to prepare students for the future.

5.3.9 Question 9: With Respect to Industry 4.0, Select Your Level of Competence in the following Software/ Technical Skills?

This question evaluates respondents' competence level in a list of technical skills that are relevant in Industry 4.0. Figure 35 depicts that a high number of the 93 respondents in this survey have zero to small expertise in all the identified technical skills except operations management, closely following this is Big Data Analytics, this suggest an overall skill deficit in the labor market, however, since these skills are industry-specific, the same type of skills may not apply to two different occupations. For example, MES is relevant to manufacturing but might not be relevant to IT.

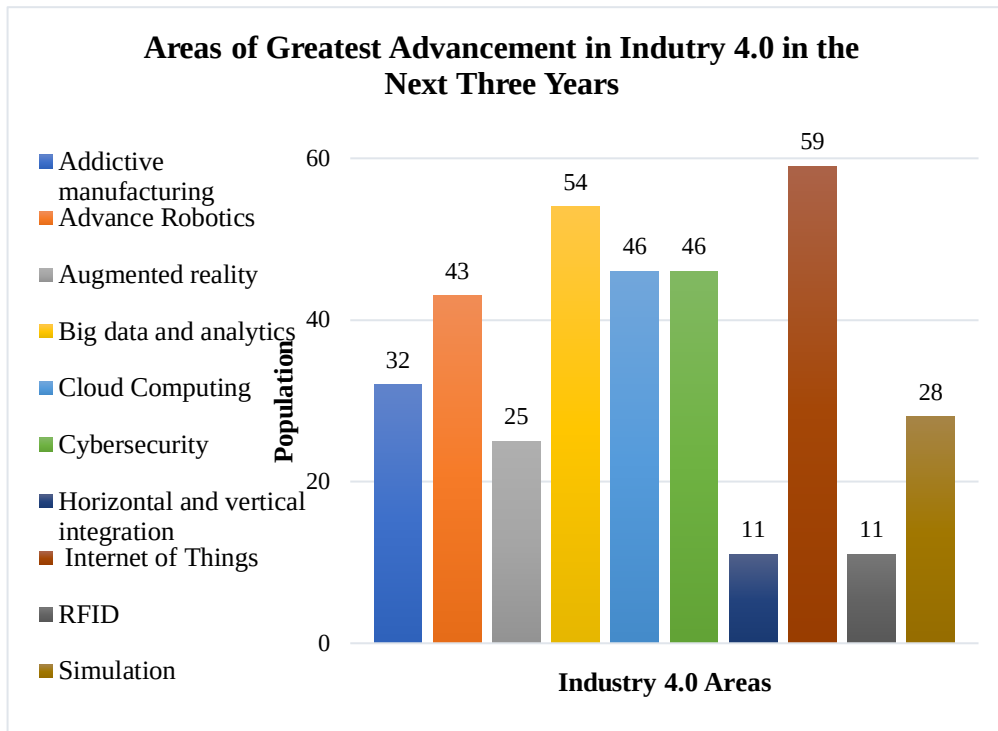


Figure 34: Areas of Anticipated Advancement in Industry 4.0 in the Next Three Years according to Industry.

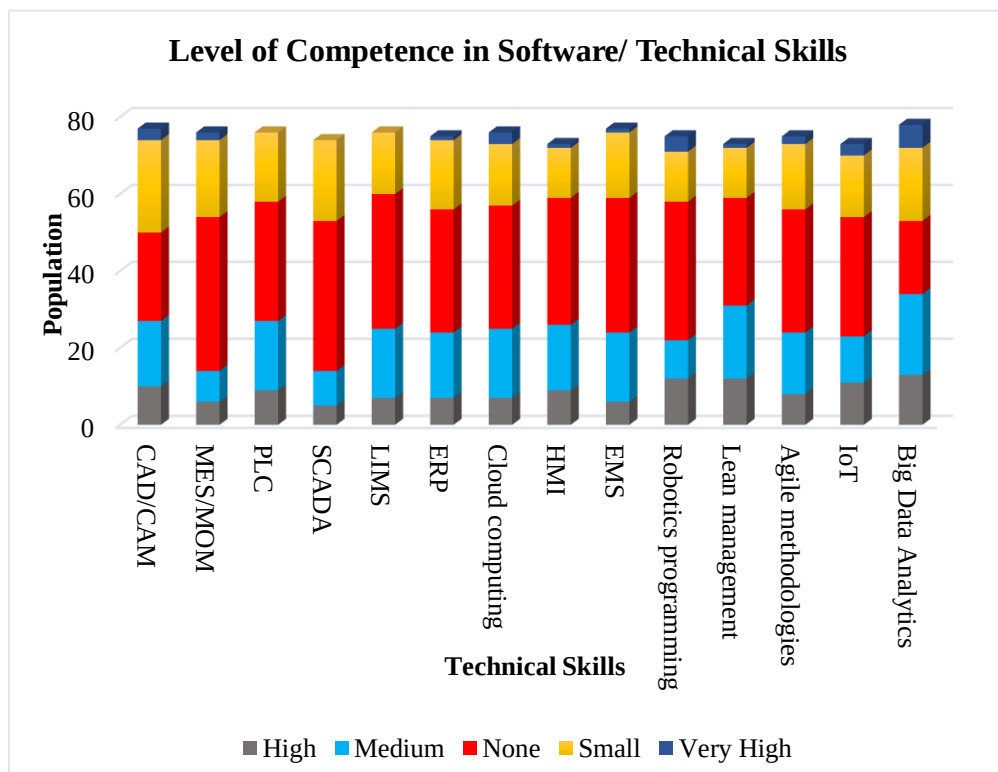


Figure 35: Respondents' Level of Competence in Software/ Technical Skills.

5.3.10 Question 10: Which Technologies/Tools are Needed in Your Field? (Can Answer More Than 1)?

This question evaluates the tools that are needed in the respective fields of the respondents. Figure 36 shows that Big Data and Real-time Data Analytics tool is mostly needed across all fields, then Cloud technologies and Sensor technology. With this revelation, IE students may need to begin to take up interests in these technologies, an effective method is through pedagogical approaches. Sensor technology, Machine-to-Machine communication, Cloud technology and Embedded systems are the prominent tools or technologies needed in the manufacturing sector.

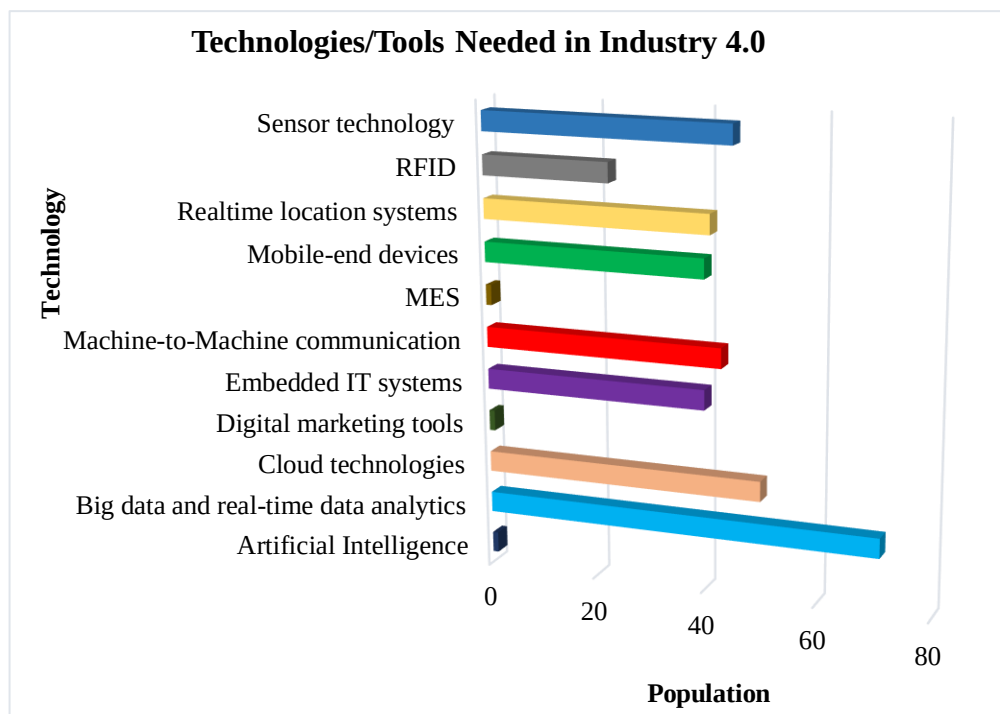


Figure 36: Relevant Technologies/Tools Needed for Industry 4.0.

5.3.11 Question 11: Which Technologies Do You Currently Use in Your Industry? (Can Answer More Than 1)

This question evaluates the tools that respondents currently utilize in their respective fields. Figure 37 shows that responses that closely mimics the responses in question

10. The low response in Artificial Intelligence and MES is quite disturbing, this may indicate that the respondents do not have a good understanding/knowledge of these areas or their pertinence to future jobs. Considering that AI is a major pillar of Industry 4.0 and WEF has predicted that there will be more Human-Machine interfacing in by 2020, the industry should build skills in AI and MES.

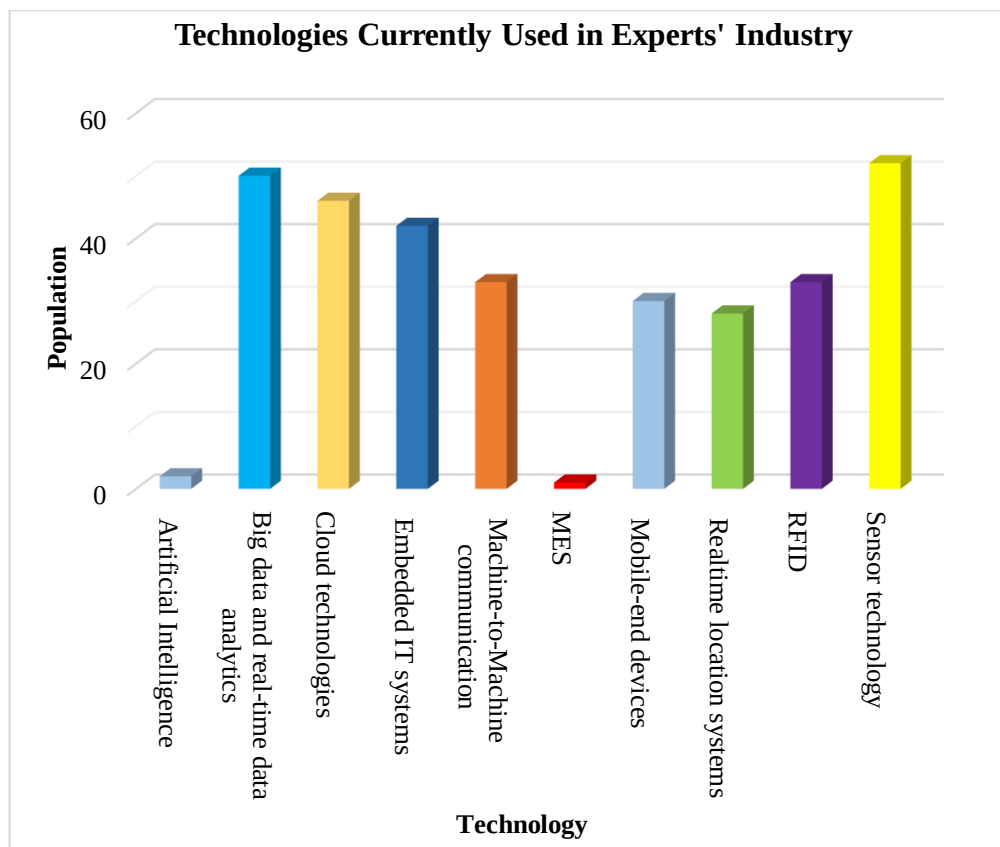


Figure 37: Technologies Currently Used by Respondents in their Industry.

5.3.12 Question 12: Select the Relevance of these Skills to the Future of Industry 4.0 in Your Field?

The responses to this question shown in Figure 38 depicts that over 50% of the respondents confirm that the listed skills are of high relevance. Across all the industries, IT Infrastructure, Data Security are highest in the relevance, followed by Data Analytics, then Automation Technology. This suggests that the respondents rate

technical skills more relevant than professional skills or the respondents currently require less of professional skills for their jobs hence they are of the opinion that this will apply in the future.

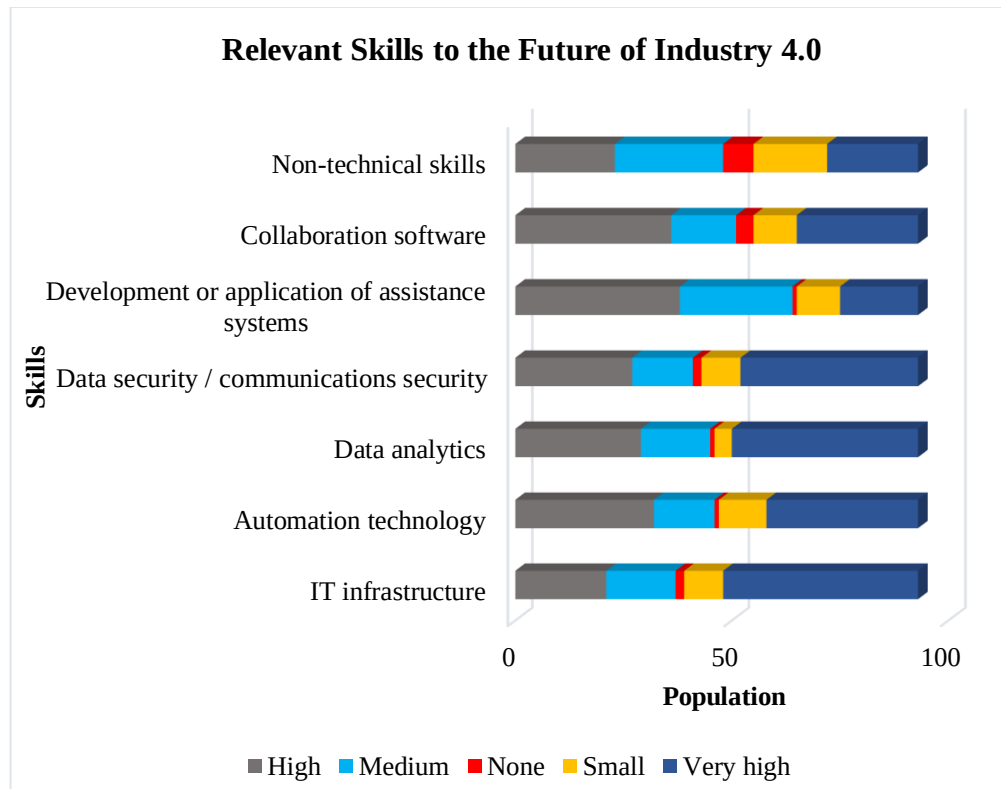


Figure 38: Relevant Skills to the Future of Industry 4.0.

Collaboration software skills measure proficiency in the use of software that aids communication between teams and effective teamwork. Examples are CloudApp, Slack, G Suites, Skype, and Teams.

Development or application of assistance systems measure the ability to create and apply technologies used to ensure that motor vehicle travel is safer.

Data security measures skills required for keeping digital production data safe from theft, contamination, and illegal access throughout its entire life cycle. They include skills such as access control, data backup, data encryption.

Data analytics entails development of descriptive and predictive models, application of statistical and quantitative analysis, and data mining to discover defects and irregularities in manufacturing predict trends, and drive decision making process. Microsoft Excel, SAP, Minitab, Google Analytics are software which industrial engineers can find helpful to develop data analytics skills.

Automation Technology involve skills that helps industrial engineers to increase production capacity and minimize cost through the use of automated equipment and production processes. Experiential learning such as team projects using digital control circuits, programmable logic controllers, and computer-controlled interface to solve real world production or supply chain problems, internships, and educational competitions.

IT Infrastructure measures skills for ensuring seamless execution, control, and monitoring of production operations through IT integration to optimize shop-floor activities. Proficiency in technologies such as IoT, PLC, SCADA, HMI, and ERP will be beneficial for industrial engineers in an industry 4.0 production facility.

5.3.13 Question 13: According to Level of Importance, Select Which Software/ Technical Skills are Relevant for Students to Learn for Careers in Industry 4.0.

This question intentionally seeks out the opinions of Industry Experts regarding the skills that IE students should learn in order to have jobs in areas of Industry 4.0. The highest overall response to this question lies in High and Very High, this suggest that

these skills are relevant for students to learn now, however the focus may be on Big Data and Analytics, IoT, and Cloud Computing. The chart below further identifies and measure technologies or tools that are relevance for industrial engineers for industry 4.0 careers.

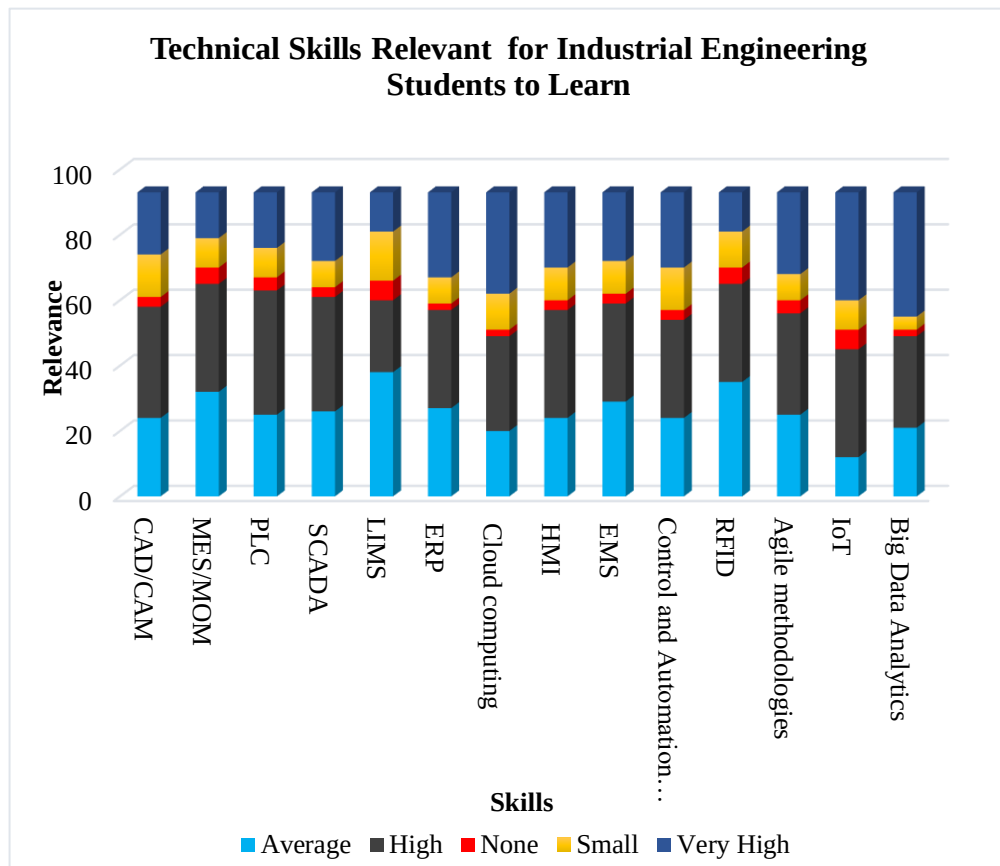


Figure 39: Technical Skills Relevant for IE Students for a Career in Industry 4.0.

5.3.14 Question 14: How Did You Acquire Your Industry 4.0 Skills and Expertise?

The contribution of universities to the acquisition of Industry 4.0 by respondents is measured with this question. The response of the 93 experts indicated that university contribution to Industry 4.0 skills acquisition of experts is 19%, while trainings outside school contributed to 67%. With this wide gap, universities must be encouraged to

engage more in practice-based pedagogy in order to give IE students competitive edge in the labor market.

Table 13: Medium of Acquisition of Industry 4.0 Skills

Mode of Industry 4.0 Skills Acquisition	Population	Percentage
Graduate School	13	14
None	4	4
Self-Funded Training Outside School/Work	34	37
Undergraduate School	5	5
Work Training/Coaching/Seminar	37	40

5.4 Courses Towards Industry 4.0 Required for the Skills Identified

In lieu of the skills identified in this study, the table below shows the recommendation for additional course contents or programs that may be adopted in IE curriculum at Eastern Mediterranean University.

Table 14: Recommendation for Additional Course Contents or Programs

Skills Identified	Course Content Recommendations
Data Analytics	The existing curriculum covers the use of tools such as Minitab, SPSS. Additional tools that may be included is Microsoft excel- pivot tables and charts. Excel also allow add-ins for big data analysis.
Automation Technology	Course contents that cover exposure to industrial automation and control seen in discrete and continuous

	manufacturing factories. CATIA V5 is a leading software that may be introduced in automation courses.
IT Infrastructure	Courses that entail introduction to the concepts of Industry 4.0, IoT systems and industrial applications in production.
Data Security	Academic seminars or programs on privacy and compliance, secure data access and transmission, password security and social engineering.
Collaboration Software	Microsoft 365, Teams software is already being utilized for teaching and academic meetings. Other social software such as Google Hangout, Discord is widely used in different spaces for collaboration.
Assistance Systems	Courses on additive manufacturing or 3D printing from the introductory to advance level may be introduced in curriculum.

Chapter 6

CONCLUSION

6.1 Summary

The world is evolving, now at a faster pace than before. Technological advancement is a major factor responsible for this evolution. The internet is a major technological advancement in today's world of Industry 4.0, the emergence of internet has led to an increase in human-machine interaction. This interaction is responsible for the enormous amount of data in circulation in industries and government. The internet, human-machine interaction, and the need to collect, manage and utilize data is influencing industries to shift from conventional processes and practices to automated systems that ensure efficiency and effectiveness of their operations. Hence in today's labor market, jobs that require human-machine interaction are in more demand.

With this demand, there is rise in the need for relevant skills – both technical and professional skills. Technical skills for exchanging information with machines and internet; professional skills for human-to-human interactions. Identification, teaching and learning of these skills is the subject on several research in recent years. This study contributes to the scholarly progress by identifying specific Industry 4.0 inspired skills for IE students who will work in various engineering industries in the future.

6.2 Conclusion of the Study

In this study, the relevant skills needed for successful careers in Industry 4.0 were highlighted from the perspective of engineering experts in the labor market on one

hand and engineering students in the universities on the other end. The contributions and expectations of people in industries and government, especially in academia towards teaching, learning and development of these skills were also discussed. Technical skills, professional skills, tools, technologies, and software of Industry 4.0 were highlighted and assessed solely based on the opinions of engineering experts and students.

It can be stated from the results of the surveys enumerated in Chapter 5 that the knowledge of Industry 4.0 in Engineering field is rather low. As people related with the concepts of Industry 4.0 in their daily life, they have gained more knowledge of the concepts. With this awareness, it can be asserted that Industry 4.0 technical skills including professional skills are expedient for students to learn in order to build successful careers in today's world. The results to question 13 and 12 of the industry experts and students survey respectively revealed the relevant software and technical skills that students may learn in order to achieve this. However, academia must step up and play a big role in the development of both domain-specific and transversal skills in students before they transition into the labor market.

Specifically, the improvement of engineering education to include skill acquisition in the areas of Industry 4.0 where the greatest advancement is envisaged is desperately needed; especially in areas such as Advance Robotics, Big Data Analytics, Internet of Things, Cybersecurity and Cloud Computing. The revision of students' course contents and engineering curricula to address the current and future skill needs of the labor in these highlighted areas Industry 4.0 is important. To conclude, universities in this age of Industry 4.0 should put invention, both new and progressive high on its

education policy and foster reforms of engineering curriculum and pedagogical system to align with emerging Industry 4.0 technologies and skillsets.

6.3 Recommendations for Future and Further Study

The limitations of this study pose salient areas for further scholarly study. Study into technical and professional skills required for careers in specific areas of Industrial Engineering such as Occupational Safety and Health Administration, Manufacturing systems, Supply Chain and Logistics, Human Factors and Ergonomics, Operations research etc. is encouraged.

Also, a study of pedagogical approaches for incorporating the development of transversal skills in the engineering curriculum in Turkey and Northern Cyprus from the high school level will help in developing more competent students and individuals in the workplace and society at large.

Lastly, I will recommend a study of Industrial Revolutions in Turkey and its impact on engineering education. Since technological and socio-economic advancement during the Industrial Revolutions is unique to countries, this study will produce custom results and recommendations for engineering education system in Turkey and Northern Cyprus by extension.

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APPENDICES

Appendix A: Questionnaire on Industry 4.0 for Industry experts

1. What is Your Industry/Field?					
Electronic/Optics/Data Processing	Food/Beverage Processing	Clothing/Apparel/Textile			
Metal Work/Machining	Electrical	Automotive			
Chemical Products	Manufacturing	IT			
Packaging	Construction/Building	Other			
2. Do You Know about Industry 4.0 Concept?					
No, I Have Never Heard of It.	I Have Heard of It But Do Not Know What It Is about.	I Have a Little Knowledge about It.			
I Know Enough to Carry Out Projects.	I Have Mastered the Concept and Already Applied It.				
3. What is Level of Your Knowledge/Expertise in the following Aspects of Industry 4.0?					
	None	Small	Medium	High	Very High
Advance Robotics Additive Manufacturing Augmented Reality Simulation Horizontal and Vertical Integration Cloud Computing Cybersecurity Big Data and Analytic Internet of Things RFID					
4. What is the Level of Relevance of Industry 4.0 to Your Field Today?					
Not Relevant			Highly Relevant		
1	2	3	4	5	
5. Rate Your Level of Knowledge in the following Skills Relevant to Industry 4.0?					
	None	Small	Medium	High	Very High
Cognitive Flexibility Creativity Logical Reasoning Data Analysis Mathematical Reasoning Judgement and Decision Making Complex Problem Solving ICT Literacy					

Troubleshooting						
6. What Tools/Technologies Do You Presently Use to Access, Analyze, and Leverage Data in Your Industry?						
Desktop Productivity Tools	Computerized Maintenance Management System (CMM)	Mobile Field Management				
Visual Scanning/Video	ERP Software Analytics	Process Automation				
Big Data Management Programs	Robotics	Data Visualization Tools				
Sensors	Cloud Computing Resources	Simulation and Modeling				
7. How Much Do You Anticipate an Advancement in Industry 4.0 Related Technologies in the Next Three Year?						
I Do Not Know	Stay the Same	Increase Slightly	Increase Significantly			
8. Which of the following Areas Relating to Industry 4.0 Do You Think There Would Be Greatest Advancement in the Next Three Years? (Can Answer More Than 1)						
Advance Robotics	Addictive Manufacturing	Augmented Reality				
Simulation	Horizontal and Vertical Integration	Cloud Computing				
Cybersecurity	Big Data and Analytics	Internet of Things				
RFID	Other...					
9. With Respect to Industry 4.0, Select Your Level of Competence in the following Software/ Technical Skills?						
	None	Small	Medium	High	Very High	
CAD/CAM MES/MOM PLC SCADA LIMS ERP Cloud Computing HMI EMS Robotics Programming Lean Management Agile Methodologies IoT Big Data Analytics Operations Management						

10. Which Technologies/Tools are Needed in Your Field? (Can Answer More Than 1)					
Sensor Technology	Machine-To-Machine Communication	RFID			
Big Data and Real-Time Data Analytics	Mobile-End Devices	Realtime Location Systems			
Cloud Technologies	Embedded IT Systems	Other...			
11. Which Technologies Do You Currently Use in Your Industry? (Can Answer More Than 1)					
Sensor Technology	Machine-To-Machine Communication	RFID			
Big Data and Real-Time Data Analytics	Mobile-End Devices	Realtime Location Systems			
Cloud Technologies	Embedded IT Systems	Other...			
12. Select the Relevance of these Skills to the Future Of Industry 4.0 in Your Field?					
	None	Small	Medium	High	Very High
IT Infrastructure Automation Technology Data Analytics Data Security / Communications Security Development or Application of Assistance Systems Collaboration Software Non-Technical Skills					
13. According to Level of Importance, Select Which Software/Technical Skills are Relevant for Students to Learn for a Career in Industry 4.0.					
	None	Small	Medium	High	Very High
CAD/CAM MES/MOM PLC SCADA LIMS ERP Cloud Computing HMI EMS Robotics Programming Lean Management RFID Agile Methodologies IoT Big Data Analytics					

14. How Did You Acquire Your Industry 4.0 Skills and Expertise?		
Undergraduate School	Graduate School	Work Training/ Coaching / Seminar
Self-Funded Training Outside School/Work	Other...	

Appendix B: Questionnaire on Industry 4.0 for Engineering Students

1. What is Your Field of Study?					
Electronics Engineering	Electrical Engineering	Food Engineering			
Mechanical Engineering	Industrial Engineering	Information Technology			
Computer Engineering	Civil Engineering	Other...			
2. What is Your Current Level of Education?					
Undergraduate	Postgraduate	Doctoral			
3. Do You Know About Industry 4.0?					
No, I Have Never Heard of It.	I Have Heard of It But Do Not Know What It Is about.	I Have a Little Knowledge about It.			
I Know Enough to Carry Out Projects.	I Have Mastered the Concept and Already Applied It.				
4. What is Level of Your Knowledge/Expertise in the following Aspects of Industry 4.0?					
	None	Small	Medium	High	Very High
Advance Robotics Additive Manufacturing Augmented Reality Simulation Horizontal and Vertical Integration Cloud Computing Cybersecurity Big Data and Analytics Internet of Things RFID					
5. On a Scale Of 1 To 5, Describe the Level of Relevance of Your Coursework to Industry 4.0?					
Not Relevant		Highly Relevant			
1	2	3	4	5	
6. With Respect to Industry 4.0, Rate Your Competence Level in the following Skills?					
	None	Small	Medium	High	Very High
Cognitive Flexibility Creativity Logical Reasoning					

Mathematical Reasoning Judgement and Decision Making Complex Problem Solving ICT Literacy Troubleshooting					
7. What Tools/Technologies Do You Presently Use to Access and Analyze Data in Your Coursework?					
Desktop Productivity Tools	Computerized Maintenance Management System (CMM)	Mobile Field Management			
Visual Scanning/Video	ERP	Process Automation			
Big Data Management Programs	Robotics	Data Visualization Tools			
Sensors	Cloud Computing Resources	Simulation And Modeling			
Software Analytics					
8. By How Much You Think There Will be an Advancement in Industry 4.0 Related Technologies in the Next Three Year?					
I Do Not Know	Stay the Same	Increase Slightly	Increase Significantly		
9. Which of the following Industry 4.0 Areas Do You Envisage a Great Advancement in the Next Three Years? (Can Answer More Than 1)					
Advance Robotics	Addictive Manufacturing	Augmented Reality			
Simulation	Horizontal and Vertical Integration	Cloud Computing			
Cybersecurity	Big Data and Analytics	Internet of Things			
RFID	Other...				
10. From the Aspect of Industry 4.0, Select Your Level of Competence in the following Software/ Technical Skills?					
	None	Small	Medium	High	Very High
CAD/CAM MES/MOM PLC SCADA LIMS ERP Cloud Computing HMI EMS Robotics Programming Lean Management					

Agile Methodologies IoT Big Data Analytics					
11. According to Level of Importance, Select Which Software/ Technical Skills are Relevant for Students to Learn for a Career in Industry 4.0.					
	None	Small	Medium	High	Very High
CAD/CAM MES PLC SCADA LIMS ERP Cloud Computing HMI EMS Robotics Programming Lean Management RFID Agile Methodologies IoT Big Data Analytics					
12. How Did You Acquire Your Industry 4.0 Skills and Expertise?					
Undergraduate School	Graduate School	Work Training/ Coaching / Seminar			
Self-Funded Training Outside School/Work	Other...				