Information Systems Frontiers
https://doi.org/10.1007/s10796-022-10308-y

Reskilling and Upskilling the Future-ready Workforce for Industry 4.0 and Beyond

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Accepted: 23 June 2022

Abstract

Industry 4.0 is revolutionizing manufacturing processes and has a powerful impact on globalization by changing the workforce and increasing access to new skills and knowledge. World Economic Forum estimates that, by 2025, 50% of all employees will need reskilling due to adopting new technology. Five years from now, over two-thirds of skills considered important in today's job requirements will change. A third of the essential skills in 2025 will consist of technology competencies not yet regarded as crucial to today's job requirements. In this study, we focus our discussion on the reskilling and upskilling of the future-ready workforce in the era of Industry 4.0 and beyond. We have delineated top skills sought by the industry to realize Industry 4.0 and presented a blueprint as a reference for people to learn and acquire new skills and knowledge. The findings of the study suggest that life-long learning should be part of an organization's strategic goals. Both individuals and companies need to commit to reskilling and upskilling and make career development an essential phase of the future workforce. Great efforts should be taken to make these learning opportunities, such as reskilling and upskilling, accessible, available, and affordable to the workforce. This paper provides a unique perspective regarding a future-ready learning society as an essential integral of the vision of Industry 4.0.

Keywords Industry 4.0 · Industrial revolution · Skill sets · Reskilling, upskilling, competencies · Experiential training · Future-ready workforce · Human capital

1 Introduction

Industry 4.0 (I4.0) is in the process of revolutionizing manufacturing and engineering all over the world. I4.0 is a virtual reality fusion system based on traditional manufacturing and transformed with cyber-physical systems, the Internet, the Internet of Things (IoT), and Industrial Internet of Things (IIoT), artificial intelligence, machine learning, hyper-converged infrastructure, deep learning, virtualization, and more to create an intelligent production system (Li, 2018, 2020; Xu et al., 2018; Li & Zhou, 2020; Xu et al., 2014). Workforce, capital, and technology are the three major components that significantly contributed to the evolution of the past three industrial revolutions. Therefore, it is time to look at the talent required to realize the vision of Industry 4.0 and beyond.

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The World Economic Forum projected in its Future of Jobs Report 2020 that half of all employees worldwide would need reskilling by 2025 (Schwab & Zahidi, 2020). This estimation does not include all the people currently not in employment. Before COVID-19, the rise of automation and new technologies transformed the world of work, resulting in an urgent need for large-scale upskilling and reskilling. Now this need has become even more critical. In a 2016 World Economic Forum report, experts projected that 65% of children entering primary school today would ultimately work in completely new job types that do not exist today (Schwab & Samans, 2016). Developing new and diverse education programs and promoting innovative curricula are some of the STEM program's primary goals that provide skills, knowledge, and attitudes needed for an entrepreneurial culture (Li, 2020).

By giving all people opportunities to develop the skills they will need to participate fully in the future workplace, we ought to create more inclusive and sustainable economies and societies where no one is left behind. Industry 4.0 is about creating a unique life-long education system that

Published online: 13 July 2022

ensures a future-ready workforce. Universities with a tradition of educating and training the world's most competent designers, engineers, technology specialists, consultants, operations professionals, and data analysts are in an exciting era to tackle these challenges quickly and collaboratively.

Life-long learning for all is becoming a reality. New skills and technologies have been introduced much faster than a decade ago. Respondents to the Future of Jobs Survey estimate that around 40% of workers will require reskilling for a length of six months. Half of the workforce will need to reskill in the next five years, as the double-disruption of the economic impacts of the COVID-19 pandemic and increasing automation that transforms jobs (Whiting, 2020). Elementary and middle school education at a young age remains mandatory and fundamental, and is the first phase of life-long learning. An upward trend of increasing job complexity has been observed during the progression of industrial revolutions. Learning throughout life, including at an older age, makes the difference in the higher education domain in the twenty-first century. However, the gap in life-long learning exists among individuals. European Commission (2020) estimated that less than two in five adults participate in learning every year in the EU, which is not enough to support the needs of Industry 4.0 and beyond. All of us should embrace the opportunities to upskill and reskill our professional skill sets and contribute to the economic development of the 21 century.

While many educational organizations and individuals might still wonder how Industry 4.0 could affect the education system, some are implementing changes today and preparing for a future when artificial intelligence (AI) and cyber-physical systems can connect their business globally. In this study, we focus our discussion on the reskilling and upskilling of the future-ready workforce in the age of Industry 4.0 and beyond. The following sections cover several key elements that contribute to training a future-ready workforce. Section 2 provides background information about the top skills needed for Industry 4.0. Section 3 discusses reskilling and upskilling of the workforce in different parts of the world. In Section 4, a life-long learning framework offers opportunities to reskill and upskill a future workforce. Finally, Section Five provides conclusions.

2 Background and Literature

Industry 4.0 is a significant transformation to the digitization of manufacturing and the creation of a cyber-physical system. I4.0 connects production and process technologies, integrates vertical and horizontal value chains, and digitalizes product and service offerings to pave the way for new production and economic value chains. This transition has an enormous impact on higher education which has a role of training talents, leading scientific innovation, disseminating knowledge, as well as preparing a future-ready workforce.

2.1 What Skills will be in High Demand?

The World Economic Forum has published several reports on the future of jobs and top skills that will play significant roles in future technology advancement (Schwab & Samans, 2016; Schwab & Zahidi, 2020). The authors summarized the perspectives of strategy officers and chief human resources managers from leading global companies about the current shifts in required skills, and recruitment across industries. These reports analyze skills needed for the labor market and track the pace of changes. A quick rate of technology adoption signals that in-demand skills across jobs will change over the next five years or longer; therefore, skill gaps will continue to be significant.

Table 1 shows the top 10 skills for 2015, 2020, and 2025 (Gray, 2016; Whiting, 2020). The top 10 skills for 2015 are listed under Column 1 on the right-hand side of Table 1, and the top 10 skills for 2020 are listed under Column 2 on the right-hand side. The middle column, column 3, compares the change of rank of the top skills in 2015 and 2020. For example, complex problem solving is ranked number 1 in 2015 and 2020, while critical thinking is moved up to number two in 2020 from its rank of number four in 2015. The first column from the left-hand side shows the changes in top skills in 2015, 2020, and 2025. For example, "Analytical thinking and innovation" is listed as the top 1 skill but was not on the list in 2015, neither 2020. "Complex problem-solving" is the third most important skill in the 2025 list but was ranked number 1 in 2015 and 2020.

For those workers who stay in their roles, the share of core skills that will change from 2020 to 2025 is more than 60% (Table 1). Seven out of 10 top skills listed under the column "in 2025" are not listed under 2020 and 2015. While between 2015 and 2020, skill requirements overlap considerably, eight out of ten top skills are the same for the two periods (Table 1).

Looking forward to 2025 and beyond (Table 1), analytical thinking and innovation skills crown the skill-set list that employers believe will grow in prominence in the next five years. Active learning and learning strategies are a new skill set that trailed behind the top one. Analytical thinking and active learning ranked number 1 and number 2 in 2025, emphasizing cognitive self-management.

Critical thinking and problem-solving skills, which were at the top of the skill list in 2020 and 2015, are now relegated to 3rd and 4th places in 2025's skill list (Table 1). But these two skills, along with creativity, have consistently been viewed as critical skill sets since the first report was published in 2016. With the avalanche of new technologies, new products, and new working processes, employees will

Table 1 Review of reports of top 10 skills on reskilling and upskilling future-ready work force

25/20/15*	in 2025	20/15*	in 2020	in 2015
1	Analytical thinking and innovation	1, 1	Complex problem solving	Complex problem solving
2	Active learning and learning strategies	2, 4	Critical thinking	Coordinating with others
3, 1, 1	Complex problem-solving	3, 10	Creativity	People management
4, 2, 4	Critical thinking and analysis	4, 3	People management	Critical thinking
5, 3, 10	Creativity, originality, and initiative	5, 2	Coordinating with others	Negotiation
6	Leadership and social influence	6	Emotional intelligence	Quality control
7	Technology use, monitoring, and control	7, 8	Judgment and decision making	Service orientation
8	Technology design and programming	8, 7	Service orientation	Judgment and decision making
9	Resilience, stress tolerance, and flexibility	9, 5	Negotiation	Active listening
10	Reasoning, problem-solving	10	Cognitive flexibility	Creativity

Data Source: Gray (2016). The ten skills you need to thrive in the Fourth Industrial Revolution. World Economic Forum, January 19, 2016; and Whiting (2020). These are the top 10 job skills of tomorrow – and how long it takes to learn them. World Economic Forum, October 21, 2020.

* 25/20/15: skills in 2025, skills in 2020, and skills in 2015; 20/15: skills in 2020 and skills in 2015

become more creative to respond to and benefit from technological changes.

Items six to 10 under 2025 (Table 1) are newly emerging skills focusing on technology-related competencies and skills, cognitive reasoning capability, and leadership, with a sharp uptake from 2020. Five years from now, over two-thirds of skills (67%) considered important in today's job requirements will change. In addition, a third of the essential skill sets in 2025 will consist of technology competencies not yet regarded as crucial to today's job requirements.

2.2 What Skills are Less Focused on?

Negotiation and people management were ranked high on the 2015 skill list. However, these skills began to drop on the 2020 list and do not appear on the 2025 list. As companies and managers increasingly use masses of data and make decisions based on data analytics, negotiation and people management retreat their positions in the decision-making process. Society expects artificial intelligence and machine learning to provide decision support information to a company's board of directors by 2026.

Similarly, soft skills in the cognitive scope, such as quality control and active listening, and emotional intelligence, considered core skills on the 2015 skill list, disappeared entirely from the top 10 skill list of 2025. Instead, this year's newly emerging items are skills in self-management such as active learning, resilience, stress tolerance, and flexibility.

2.3 Emerging Disruptive Technology in Industry 4.0 and Beyond

The advancement of disruptive technology accelerates the reskilling requirements. The global supply chain, for example, has already experienced a great deal of change in the past five years. Online shopping, e-commerce, automated warehouse operations, and digitized seaport shipping information exchange are a few examples. Disruptive technologies are opening up new possibilities for society, providing innovative technology applications, novel materials, and processes to create products and services that until recently were unimaginable. As a result, those working in the manufacturing and service sectors will need new skills. Mobile internet, cloud technology, and artificial intelligence are already impacting how we work. While quantum computing and 6G are still in their early stages of use, the pace of change will be fast. Table 2 lists seven disruptive technologies that play an important role in transforming our society in a digital era.

In the next ten years, both manufacturing and service firms will have to adapt to or adopt Industry 4.0 principles and technologies to survive the competition. The vast majority of business leaders (94%) now expect employees to pick up new skills on the job (Whiting 2021). They believe that investing in the right people and the right skillsets today ensures a favorable position well into the future. Based on the literature, we discuss seven vital disruptive technologies that require significant skill upgrade for a future-ready workforce. These technology groups are far from comprehensive, but they can serve as a guideline for organizations to formulate their technology portfolio and invest in reskilling and upskilling their employees and staff.

Artificial Intelligence (AI) Since 2000, particularly after 2015, the development and utilization of artificial intelligence (AI) have escalated following the rapid growth of sensors and computer chips, the evolution of algorithms, and big data support. AI has been recognized as a strategic information technology innovation tool to improve companies' competitiveness. AI technologies, such as natural

Table 2 Disruptive Technology in Industry 4.0

#	Technology for Industry 4.0	
1	AI & ML	Artificial intelligence is the ability of a digital computer or computer-controlled robot to perform tasks commonly associated with intelligent beings (https://www.britannica.com/technology/artificial-intelligence; Chen et al., 2021)
2	Quantum Computing	Quantum information technology is a new paradigm that can process more than digital data consisting of 0 and 1 (Sigov et al., 2022). Quantum physics incorporates the digital revolution into the physical world and provides new directions in artificial intelligence and nanotechnology (Kim, 2017)
3	5G & 6G	5G is a generation of cellular networks designed to enhance the efficiency of data transmission. 6G will connect everything, provide full dimensional wireless coverage, and integrate all functions, including sensing, communication, computing, caching, control, positioning, radar, navigation, and imaging, to support full-vertical applications
4	IoT, IIoT	IoT and IIoT connect the network of physical objects (https://www.oracle.com/internet-of-things/what-is-iot/). In a supply chain, IoT links fabrication and material handling equipment, remote sensors for freight transport, and tracking systems for vehicles and other assets
5	Data Sciences & Business Intelligence	Data Science requires coding, data mining, analytical skills, and modeling to extract value and meaning from the data. In addition, human–machine interaction, quantitative skills, and understanding of information technology are regarded as essential skills in data sciences and business intelligence (Darmont et al., 2022)
6	Cybersecurity	Cybersecurity is a measure to protect a computer or computer system against unauthorized access or attack (https://www.merriam-webster.com/dictionary/cybersecurity). A critical step in preventing cyber threats is finding adequate and feasible ways to encourage employees and end-users of various technologies to protect their individual and organizational information assets (Sigov et al., 2022)
7	Green Energy	Green energy comes from renewable sources. Green energy is considered clean, sustainable, or renewable energy. A clean energy plan is an essential integral part of Industry 4.0, underscored by global leaders, energy sector administrators, and prominent corporate executives

language processing, machine learning, and deep learning, bring sophisticated data analysis capabilities to applications across various industries (Chen et al., 2021). For example, AT&T investigates how to use AI algorithms to enable drones to check and repair base stations. SK Telecom in South Korea applied machine learning to analyze network traffic to detect anomalies and strengthen network operations (Chen et al., 2021). Although some AI initiatives have been adopted in leading technology companies, many applications of AI are still at their conceptual stage. As a result, they have not generated much commercial value, particularly in network management and predictive maintenance applications.

From data collection to organizational architecture design, the AI development strategy and AI project prioritization are as complex as the technology itself. To successfully leverage the benefits of AI applications, researchers and industry experts need to build more powerful algorithms, use more significant amounts of data and computing power, and rely on centralized cloud services.

Quantum Computing Quantum Computing is a disruptive technology that tries to understand the processing and transmission of information using quantum mechanics principles. It integrates quantum effects in physics into the study of Information and Communication Technology (ICT), including theoretical issues in computational models and experimental topics in quantum physics. As a result, quantum technologies are anticipated to create a massive paradigm shift in how Industry 4.0 operates, which incorporates the digital revolution into the physical world and provides new directions in artificial intelligence and nanotechnology (Kim, 2017).

Current computing technologies have limitations due to the restriction of bits of 0 and 1. The computation must be done with bits in storing or processing data. Quantum information technology is a new paradigm that can process more than digital data consisting of 0 and 1 (Sigov et al., 2022). If quantum technology is applied to Information and Communications Technology (ICT), it will enable rapid computational processing and un-hackable internet systems. It is expected that the next generation of ICT will overcome the limitations of existing digital computers (Sigov et al., 2022). An internet based on quantum physics promises inherently secure communication. In 2020, a research team headed by Stephanie Wehner at Delft University of Technology built a network connecting four cities in the Netherlands entirely through quantum technology. Messages sent over this network would be unhackable (Temple, 2020). A team in China used the technology to construct a 2,000-km network backbone between Beijing and Shanghai. Google has provided the first clear proof of a quantum computer outperforming a classical one, although a full-scale quantum computer has not yet been developed.

5G and 6G 5G is a generation of cellular networks designed to enhance the efficiency of data transmission. 5G networks provide higher data rates, lower latency, massive device connectivity, higher capacities, better consistent service quality, and lower cost than 4G networks (Sigov et al., 2022). However, 5G is insufficient for IoT devices to exchange various data types in real-time. 6G as the next generation of 5G is at the corner. 6G will exhibit more heterogeneity than 5G and support applications far beyond anything seen. 6G will connect everything, provide full dimensional wireless coverage, and integrate all functions, including sensing, communication, computing, caching, control, positioning, radar, navigation, and imaging, to support full-vertical applications.

Networking, IoT, and IIoT Industry 4.0 has dramatically impacted the number of networking professionals in manufacturing and other critical sectors. Some examples of Industrial IoT (IIoT) and networking technologies are intelligent factories, connected fabrication and material handling equipment, remote sensors for freight condition monitoring and inspection, automated infrastructure and smart metering for utility management and energy-saving efforts, and tracking systems for vehicles and other assets. Facing the interconnected world, all businesses will need many more networking and IoT specialists than they currently employ. For example, the American Bureau of Labor Statistics expects the U.S. to add more than 15,000 jobs in network and computer systems administrators[1] by 2029. This is an example of the many disciplines required in this exciting field.

The Industrial IoT extends Information Technology (IT) to Operational Technology (OT), adding intelligence to manufacturing equipment, processes, and management (Umar, 2005; Ustek-Spilda et al., 2021). The Industrial IoT (IIoT) refers to interconnected sensors, instruments, and other devices networked with industrial applications that enable data collection, exchange, and analysis (Sigov et al., 2022). The IIoT is an evolution of a distributed control system (SDS) that allows for a higher degree of automation by using cloud computing to refine process controls.

Data Science and Business Intelligence By 2025, nearly 30 percent of the data will be of the "real-time" variety.[2] Real-time data refers to data gathered from customer insights or enterprise hardware and software as the gears of industry turn, rather than after the fact. As information technology and operational technology converge, companies begin to find new ways to connect. Data collected from suppliers, customers, and enterprises can be aligned with detailed production information and be fine-tuned in real-time. The digital and physical worlds have become irrevocably linked with machines, systems, and people, which are able to exchange information automatically.

Digital skills such as coding skills, data analytics, human–machine interaction, and understanding of information technology were regarded as basic skills because they will be required in the manufacturing industry by employees. The vast amount of data is not helpful unless we have human insights to make sense of it. We will need many more data scientists to write algorithms and build AI to help us make predictions and reasonable decisions based on the data and facts. The U.S. Bureau of Labor Statistics estimates 19% job growth for computer and information research specialists by 2026.[3]

Cybersecurity In a digital era, technologies, such as computer systems, the Internet, and smart devices, play a fundamental role in everyday life. However, while we enjoy the convenience and efficiency provided by the new technologies, we face new risks and threats caused by using technology. In recent years, businesses in all industries and of all sizes have experienced the increased frequency, volume, and sophistication of cyber-attacks (Lu & Xu, 2018). For example, on May 7, 2021, an American oil supply system, Colonial Pipeline, suffered a ransomware cyberattack that impacted the computerized equipment that operates the pipeline.

In 2020, the US government decided to collect data on the 330 million people living in the country while keeping their identities private. The data is released in statistical tables that policymakers and academics can utilize when writing legislative documents or conducting research. By law, the Census Bureau must ensure that it can't lead back to any individuals (Temple, 2020); so the census data scientists added some "noise" into the data. For example, it might change a resident's age or race to hide their identity. Differential privacy is a mathematical technique that makes this process rigorous by measuring the degree of privacy increases when added noise. Apple and Facebook already use the method to collect aggregate data without identifying particular users (Temple, 2020). The US Bureau of Labor Statistics estimates a 20% job increase in information security analysts by 2026.[4]

Green Energy A clean energy plan is an essential integral part of Industry 4.0, underscored by global leaders, energy sector administrators, and prominent corporate executives.

[1] https://www.bls.gov/ooh/computer-and-information-technology/network-and-computer-systems-administrators.htm

[2] https://www.zdnet.com/article/by-2025-nearly-30-percent-of-data-generated-will-be-real-time-idc-says/

[3] https://www.bls.gov/ooh/computer-and-information-technology/computer-and-information-research-scientists.htm

[4] https://www.bls.gov/ooh/computer-and-information-technology/information-security-analysts.htm

According to the US Department of Energy,[5] "the clean energy industry generates hundreds of billions in economic activity and is expected to grow rapidly in the coming years." As a result, there is a tremendous economic opportunity to develop green energy, including solar, wind, water, nuclear, geothermal, bioenergy, and more. Moving forward, the world will continue to drive strategic investments in the transition to a cleaner and more secure energy future.

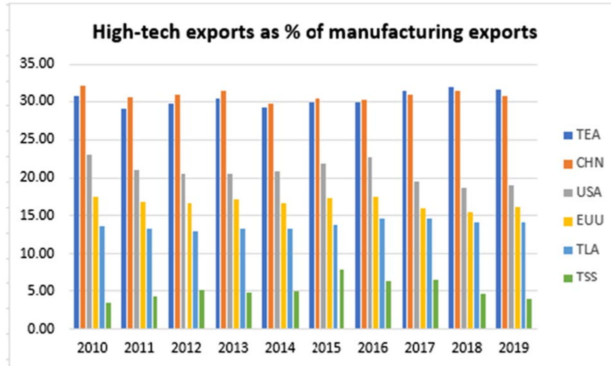
As the demand for renewable energy continues to increase, the industry is looking to recruit high-caliber candidates to drive the green energy business forward. According to the U.S. Department of Energy, the solar workforce increased by 25% in 2016, while wind employment increased by 32% (Mellett & Finnell, 2021). Although this may seem obvious, work in the energy sector requires a range of technical skills to excel as an employee and eventually as a leader to lead teams and projects. In addition, employees in the renewable energy sectors need an excellent grasp of scientific principles and concepts to make good decisions based on facts and factual data rather than opinion or perception.

2.4 Trend of High-Tech in Manufacturing Exports and Patent Applications

As the speed at which emerging technology evolves, manufacturing companies have increased the rate at which they design, develop, and export high-tech products. Therefore, it becomes essential that manufacturing and supply chain managers support the development of workforce capabilities (Doherty & Stephens, 2021). To better picture technology advancement and the need for workforce skill re-tooling, we present the trend of digitalization using the metrics of high-tech in manufacturing export and patent applications from the World Bank. Table 3 shows high-tech exports as a percentage of manufacturing exports. The World Back defines high-tech exports as "products with high R&D intensity, such as in aerospace, computers, pharmaceuticals, scientific instruments, and electrical machinery."

In 2017, 2018, and 2019, 30% of the manufacturing exports of East Asian and Pacific countries and China are high-tech products (Table 3). At the same time, high-tech exports accounted for about 15 to 20% of the total exports in the U.S. and European Union countries. On the other hand, Sub-Saharan African countries exported significantly fewer high-tech products than East Asian and Pacific countries. Therefore, there is an excellent opportunity for African and Sub-Saharan African countries to catch up with the wave of Industry 4.0. Education, training, and skill re-tooling will

Table 3 High-tech exports as % of manufacturing exports



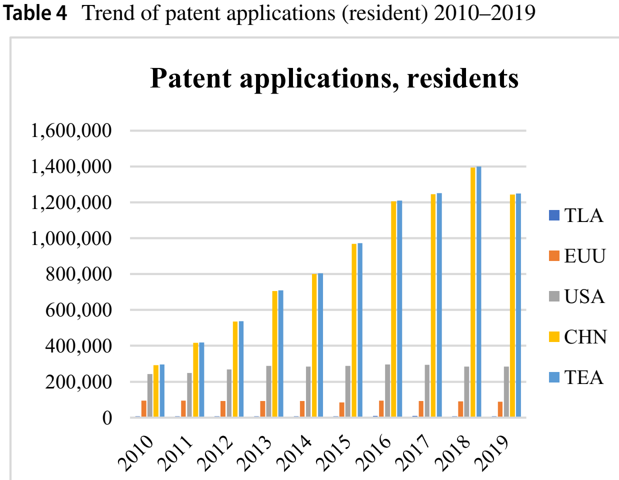
The author's work used the data from the World Bank's data source, https://data.worldbank.org/indicator/TX.VAL.TECH.MF.ZS?view=chart

TEA East Asia & Pacific (IDA & IBRD countries), *CHN* China, *USA* United States, *EUU* European Union, *TLA* Latin America & the Caribbean (IDA & IBRD countries), *TSS* Sub-Saharan Africa (IDA & IBRD countries)

play an essential role in enabling African countries to catch up with the high-tech wave in the era of Industry 4.0.

We further analyzed the number of pattern applications, payments of use of intellectual property, and the receipts of use of the intellectual property. These metrics show the growth of high-tech innovation and the global sharing of technology innovation. An upward trajectory of pattern applications is shown in Tables 4 and 5. A product or process that provides a new way of doing things or offers a new technical solution to a problem will be eligible for patent

Table 4 Trend of patent applications (resident) 2010–2019



The author's work used the data from the World Bank's data source, https://data.worldbank.org/indicator/TX.VAL.TECH.MF.ZS?view=chart

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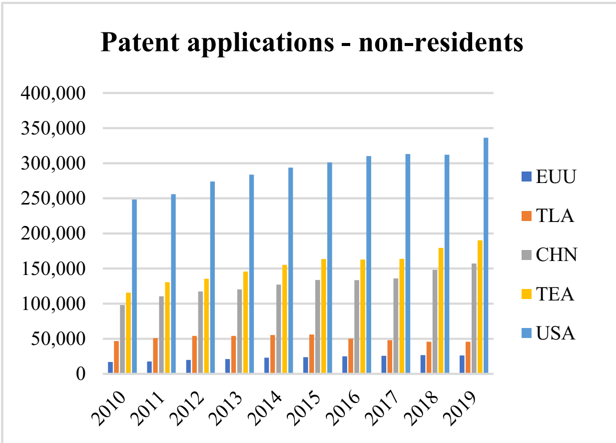
[5] https://www.energy.gov/science-innovation/clean-energy

Table 5 Trend of patent applications (non-resident) 2010–2019



The author's work used the data from the World Bank's data source, https://data.worldbank.org/indicator/TX.VAL.TECH.MF.ZS?view=chart

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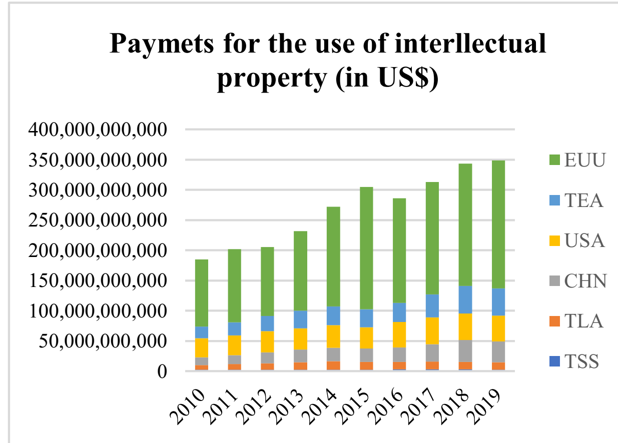
Table 6 Payment for the use of intellectual property



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application (the World bank). Patent applications are generally filed through the Patent Cooperation Treaty procedure or with a national patent office by a resident of a country or a non-resident of the country. In ten years, from 2010 to 2019, the number of patent applications filed by the residents in East Asia & Pacific countries and China increased steadily at a rate of greater than 300%. On the other hand, the patent filing rate by residents in EU countries and the United States remained stable; and it did not show an upward trajectory as observed in East Asia & Pacific countries, and China.

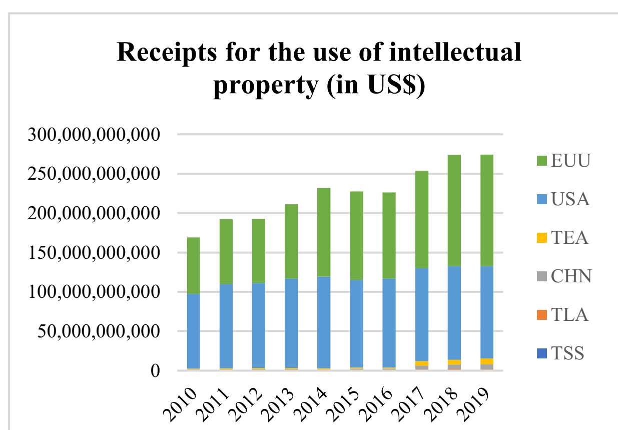
Tables 6 and 7 show payments for using intellectual property and receipts for letting other companies use its innovation. The authorized use of proprietary rights (such as patents, trademarks, copyrights, industrial processes, and designs, including trade secrets and franchises) are granted through licensing agreements. Companies in the EU and the US have collected the most receipts by letting other companies use their intellectual properties.

The rapid growth in high-tech export, patent application, and receipts for letting others use intellectual property show that it is essential for society to emphasize workforce skilling, reskilling, and upskilling because technology innovation and workforce's knowledge and skill level go hand in hand.

3 Global Effects of Reskilling and Upskilling of Workforce

Industry 4.0 has shifted manufacturing operations away from mechanical technologies and toward digitalization. Responding to the acceleration of digital transformation, industries worldwide have introduced advanced technologies to their production lines and processes. With increasing trade and communication, more and more companies extend their reach across continents and oceans. Today, goods are transported worldwide by container ships, trucks, air, and various transportation modes. Business activities, including material acquisition, production of goods, facilities management, professional services and maintenance, and logistics

Table 7 Receipts for the use of intellectual property



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TEA East Asia & Pacific (IDA & IBRD countries), *CHN* China, *USA* United States, *EUU* European Union, *TLA* Latin America & the Caribbean (IDA & IBRD countries), *TSS* Sub-Saharan Africa (IDA & IBRD countries) outsourcing, can all be part of international processes. Industry 4.0 is revolutionizing and digitizing businesses and has a powerful impact on globalization by changing the workforce and increasing the mobility of people around the World. The need for upskilling and reskilling the workforce is a global issue since international trading and outsourcing prevail in today's economy (Li & Lu, 2021; Li, 2018; Xu, 2011). In the following section, we will discuss several sample cases regarding workforce training and skilling efforts in developing economies and developed countries.

Africa – A Developing Economy The application of Industry 4.0 technologies has a significant impact on the developing countries in Africa, which is relatively weak in human capacity development. Adepoju and Aigbavboa (2021) provided insightful facts to support the need for reskilling and upskilling the workforce in Africa in the Industry 4.0 working environment. "Nigeria is a developing country with the largest economy and population in Africa. The Nigerian economy accounts for approximately 55% of the West African GDP, 35% of Sub-Saharan Africa's GDP, and one-fifth of the African population. As a result, the economy has been acknowledged as one of the fastest-growing economies in Africa. However, there is still a challenge of low human capital in Nigeria" (Adepoju and Aigbavboa, 2021). The most recent report on world human capital ranking shows that Nigeria, the largest economy in Africa, is ranked 152 out of 157 economies in the world (The World Bank, 2020). Therefore, it is obvious the next frontier for technology skill advancement will be in Africa.

Maisiri and Van Dyk (2021) explored Industry 4.0 skill needs in South Africa. Based on surveys with industry experts, they reported that the South African manufacturing industry consists of a significant percentage of the low-skilled workforce that deviated from the higher skill levels required in the Industry 4.0 era. The participants of their study pointed out that Industry 4.0 makes jobs more meaningful and interesting by enabling lower-skilled people to do higher-skilled jobs using technologies such as augmented reality and virtual reality. Industry 4.0 technologies enable employees who have been stuck in low-paying jobs and menial labor to be more relevant and perform higher functions in their companies (Maisiri & Van Dyk, 2021). Though the South African manufacturing industry has adopted Industry 4.0 principles and technologies and made a noticeable contribution to the country's economy, its manufacturing industry is currently characterized by significant unskilled and semi-skilled workers. Thus, workforce reskilling and upskilling remain vital to the success of the country's economic development.

Central and East Europe—former Eastern-Bloc Countries After the falling down of the Berlin Wall, the former socialist economies have reconnected with the western European countries and the global economic systems. Investors have been attracted by the low-cost labor, the local government's support, and cultural and geographic proximity to Western European markets (Olejniczak et al., 2020). Major automakers in the world have set up production facilities in the former Eastern-Bloc countries. Several Japanese carmakers built their capital-intensive automotive factories in the Visegrád Group, a cultural and political alliance of four Central European countries, the Czech Republic, Hungary, Poland, and Slovakia. The Japanese automakers introduced their unique management style to European workers. Paired with advanced automation in the form of Industry 4, Japanese managers embedded regular job rotation to develop a more flexible workforce that possesses multi-skills. They introduced quality circles and the kaizen system to workers at the factory level. The Japanese automakers successfully transferred the concept of on-the-job training and development of multi-skilled employees to their European subsidiaries, resulting in a completely new system in an Industry 4.0 production environment that is neither a copy of the original model nor a replica of existing local patterns.

Mexico – An Emerging Economy As a neighboring country of the U.S., Mexico is a favorable location for American manufacturers to expand their facilities because of the low cost of labor and proximity. Mexico is one of the largest auto manufacturers and auto parts exporters. Yet, many manufacturers in Mexico still use legacy systems that run production with data siloes or cumbersome processes, which contribute to delays, outdated information, and lower productivity. The reality is that many manufacturing companies in Mexico are behind with technology (Lara, 2019). In addition, the idea of digitalizing manufacturing is not as mature in Mexico as it is in the U.S., Europe, and China. In order to set the path for Industry 4.0 and the Industry Internet of Things, Mexican industry managers have begun to think about how to implement technology on the shop floor. Connecting equipment, machines, and sensors on the shop floor allows workers to observe how production performs and comprehend what is working and what needs to be improved.

Continuing with the current advancement of technology could mean a significant displacement of qualified and unskilled jobs, which could increase the unemployment rate (Santiago, 2020). To adopt and manage Industry 4 technologies, workers will need a high content of knowledge and creativity. On the other hand, employees who have a less-technology-intensive job are at risk of being replaced by an imminent development of AI. Therefore, reskilling and upskilling the workforce is an urgent priority for Mexico to keep up with the pace of digitalization.

Norway and UK – the Developed Economies The developed countries have made a substantial investment in advanced technology in the Industry 4.0 era. In a study of analyzing the similarities and differences of supports for the development and diffusion of robotics and AI in the United Kingdom (UK) and Norway, Lloyd and Payne (2019) considered country effects by exploring the role of institutions and social actors in shaping technological change in the two countries. Drawing upon interviews with technology experts, employer associations, and trade unions, they examined public policies support for the development and diffusion of robotics and AI, along with potential consequences for employment, work, and skills. Consequently, both UK and Norway have provided more funding for R&D, including increased resources for universities and research institutes to train, upskill, and reskill the future workforce.

Current debates in the developed countries around advanced technologies such as robotics and artificial intelligence are dominated by concerns over the threat to employment amid widely varying estimates of potential job losses (Lloyd & Payne, 2019). The published literature covers a range of perspectives regarding narrow and broad approaches to innovation. The former approach highlights scientific and technological innovation and the links between publicly funded R&D institutions and firms (Edquist, 1997). The latter focuses on the role of employees' learning by doing and interacting inside organizations to support or drive incremental innovation (Lundvall, 2016). The Nordic countries implement learning-rich forms of industrial organizations that are linked to education systems, strong vocational training, and collective regulation of the labor market (Arundel et al., 2007; Lloyd & Payne, 2019).

In contrast to Norway, the UK's manufacturers are on a low level of automation. When reflecting on the industry's readiness for Industry 4.0, interviewees stated that some manufacturers in the UK had not done industry 3.0 yet. However, the researchers in the university robotics centers and funding bodies noted that substantial resources had been invested in developing technologies for health and social care, such as robotic surgical tools and interactive assistive robots to support independent living (Lloyd & Payne, 2019).

China – the World Manufacturing Hub China has gone through 40 years of economic reform and is undergoing another significant economic undertaking of domestic-led consumption, services, and innovation. Since 1978, China's economic development has evolved from an export-led economy to a global manufacturing hub and an investment-led economy. In response to the recent sanctions from the U.S. government on exporting high-tech products to China, China has prioritized science and technology development to focus more on self-made critical technologies. This new economic development goal has compelled China to examine its industrial policies and strategies over the past 40 years and formulate its investment in an Industry 4.0 economy.

China is modernizing and digitizing its industry like the rest of the world and is now turning its attention to ensure that its workforce will have the skills and knowledge needed for the next phase of the country's economic journey, especially in the high-tech area. Thus, reskilling, upskilling, and vocational training are urgent tasks to transform China's workforce into lifelong learners. Currently, finding employment after graduation from a technical or vocational school is not always straightforward in China (Woetzel et al., 2021). Germany sets a good example for China and other countries. The German education system integrates vocational schooling with industry needs. Students of German vocational programs "find it relatively easy to be recruited by companies in their skill area, and they have comparable job satisfaction and career trajectory levels with their counterparts who pursued an academic path" (Woetzel et al., 2021).

China is rebalancing its economic structuring by moving toward high value-add innovative industries, such as robotics, AI, and semiconductor products. However, some employees are not able to keep up with the change. A recent study on the first job insights (Li et al., 2018) indicated that the average time in the first job for the generation born in the 1990s in China was 19 months; the employees who were born in the 1980s spent 43 months in their 1st jobs, and those who were born in the 1970s stayed on their 1st job for 51 months. The average time on the 1st job has decreased exponentially over the past three decades. However, many Chinese employers lack comprehensive training programs. At the same time, some Chinese companies regard reskilling and upskilling as an expense rather than an investment in their human resources.

In general, China has an education system that serves its industrial economy effectively. However, the gap exists in reskilling and upskilling its future workforce and training life-long learners (Wu & Ye, 2018). In August 2021, A draft revision of the Science and Technology Progress Law was submitted to the Standing Committee of China's 13th National People's Congress for deliberation. The draft stipulates focusing on major national strategic tasks, promoting core technology research, and achieving self-reliance on core technology. Thus, China will focus on workforce skilling, reskilling, and maintaining a sustainable talent pool.

In summary, in the Industry 4.0 era, a transformation of education and skill-development systems appears necessary to all industries. Around the world, work is changing as digitization and automation spread. As a result, millions of people will need to update and refresh their skills, and some will change occupations (Garbellano & Veiga, 2019). An estimated one-third of the global occupational transitions will happen in the twenty-first century. A few practices and models we discussed above, such as the Japanese automakers' implementation of on-the-job training in Central and Eastern Europe, Mexico's on-the-job training experiments, the Nordic countries' learning-rich forms of work organization, and China's new priority of workforce skilling and reskilling, could offer a helpful reference point to all.

4 A System Driven Blueprint for Reskilling and Upskilling the Future-ready Workforce

In the Industry 4.0 era, the world faces massive change and transformation. Rapid advances in industrialization and digitalization have spurred tremendous progress in developing the next generation of technologies, including AI and machine learning, quantum computing, 6G, IoT, IIoT, Big Data and business intelligence, cybersecurity, and green energy. Industry 4.0, which is different from the previous industrial revolutions, places a premium on human capital and intellectual resource for innovation.

In the twenty-first century, knowledge dissemination, learning, and education are more accessible, to more people, in more places, and in more ways than ever before in human history. We have observed and experienced an upward trend of technology innovation (Tables 3 and 4), increasing job complexity and technology integration during the progression of industrial revolutions. The success of Industry 4.0 depends not only on technology but also on people. A significant change in the competency requirements has been recorded in the global supply chain and manufacturing industry (Ahmad, 2019). The vision of advanced manufacturing will be realized through the effort of a future-ready workforce (Li, 2020).

The several studies that we cited in Section 3 of this article ventured into examining the subject of Industry 4.0 skills in South Africa, Mexico, Central Europe, and other countries. The conclusions of these studies result in a broad consensus that the onset of intelligent software systems, AI, and machine learning will not lead to mass unemployment. Instead, the likelihood is that many job functions will be downgraded or even disappear, while training, retraining, re-skilling, and upskilling will be necessary to prepare today's students and workforce to be more creative to respond to the call of Industry 4.0 (Ahmad, 2019; Li, 2020; Schwab & Zahidi, 2020).

As technology evolves, some people are not able to get good jobs due to a lack of the right skills, while others are afraid of low-skilled jobs being threatened by automation. As a result, skill gaps are inevitably increasing unless today's workers, who are at most risk of losing their jobs, learn new technology and take the opportunity to acquire the skills required for future employment. While certain higher-skilled workers have seen their pay increase, many others have seen median wages stagnate, and their job security becomes more precarious (Moritz & Zahidi, 2021). Indeed, by focusing on scalable reskilling and upskilling, people would be fully equipped to participate in economic development, reducing inequality and leading to better social stability (Moritz & Zahidi, 2021).

4.1 Scenario for Skilling and Upskilling

The latest *Future of Jobs* report by the World Economic Forum (Schwab & Zahidi, 2020) estimated that by 2025, 85 million jobs might be displaced by a shift in the division of labor between humans and machines, while 97 million new jobs that do not exist today may emerge. These new jobs are more adapted to the new division of labor between humans, machines, and algorithms (Schwab & Zahidi, 2020). The top skills which will rise in the lead include analytical thinking and innovation, active learning, critical thinking, complex problem-solving capability, and skills in self-management such as stress tolerance and flexibility. In their report, Schwab and Zahidi (2020) stated that 84% of employers would engage in digitalized working processes, including a significant expansion of remote work. Therefore, those currently unemployed should emphasize learning digital skills such as big data analytics, cybersecurity, and information technology.

4.2 Defining Reskilling and Upskilling through College Education

As the world is experiencing digital transformation in Industry 4.0, we are experiencing a paradigm shift that has profound implications for the workforce and will affect strategy, talent, innovation, and business models. The 21st-century workforce is committed to 21st-century technologies and skills (Li, 2020). To advance their work skills, the future-ready workforce will take upskilling and reskilling continuously as they advance their career and secure their employment. Upskilling means that employees gain new skills to help in their current job responsibility. For example, an accountant, who used to use an abacus for accounting and computing, learns digital spreadsheets to balance the company's balance sheet.

On the other hand, reskilling means employees need the knowledge and skills to take on different or entirely new roles. For example, the switchboard operator position disappeared after the cell phone became a primary communication device. As a result, those operators will need to reskill to take on a new career.

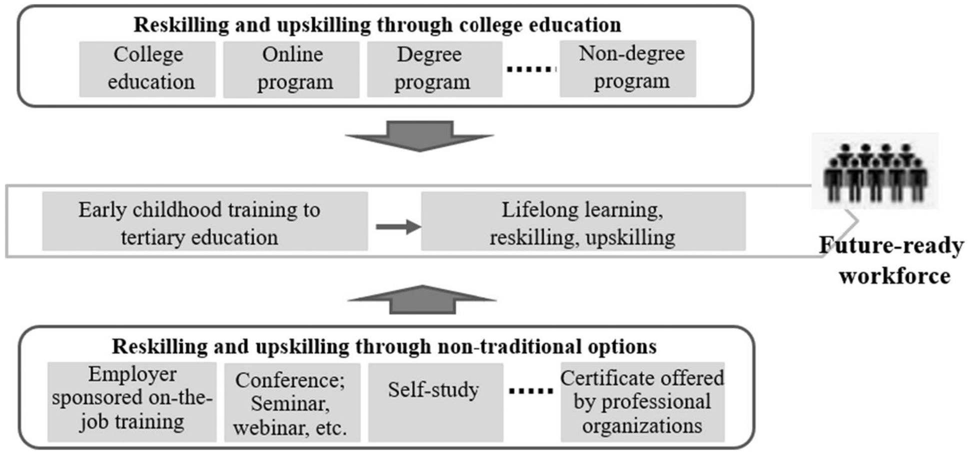

Fig. 1 A Blueprint of Workforce Reskilling and Upskilling

4.3 Which Industrial Sectors Need the Most Reskilling and Upskilling?

The new digitalization revolution will profoundly impact employment in the coming years. Nearly every job will change, and the overwhelming majority of today's employees will need to learn new skills. Ellingrud, Gupta, and Salguero from McKinsey and Company (2020) estimated that 39 to 58 percent of work activities in operationally labor-intensive sectors could be automated due to these tasks' predictable and repetitive nature. To assume a new role, workers in traditionally labor-intensive sectors, such as manufacturing, food service, retail, agriculture, mining, etc., will need reskilling. Some senior workers, whose skills were valued when they started their careers, have been left behind by the demand for new skill requirements. The workers in the labor-intensive sectors may need more reskilling than those with higher education training. There are increasing new job opportunities, but to take on new jobs, one needs to have the skills and knowledge that industries seek.

To a certain degree, the advancement of technology has attributed to job polarization. Skill-biased technical change in recent decades may have benefited skilled workers more than unskilled workers. Some tasks are easily substitutable, easily codifiable, and can be easily automated; others are not. Therefore, while the relative supply of more skilled workers has increased since the mid-1980s, the demand for skilled labor increased even more because of technological change. Information technology alone can explain between 60 and 90% of the estimated increase in the relative demand for college-educated workers from 1970 to 2000 (Kim & Park, 2020). In summary, in a labor-intensive industry, routine tasks will need reskilling while skilled professionals need upskilling.

4.4 A Reskilling and Upskilling Collaborative Ecosystem in the Era of Industry 4.0

Both employers and employees recognize that work is becoming digital, and this new environment requires updated skills. In responding to growing demands across various occupational sectors for multi-talented and highly skilled workers, more institutions have invested in multiple innovative approaches emphasizing the integration of skill-sets training. The Industry 4.0 smart systems emphasize the need to shift from focusing on automation to an intelligent collaboration between humans and machines. As such, we propose a reskilling and upskilling blueprint that is at the heart of human capital development and lifelong learning in the era of Industry 4.0 (Fig. 1). The system concept that consists of technology, people, and organization motivates the creation of the innovative skill-update program. Figure 1 summarizes and recommends steps and options necessary for the workforce to reinvent, re-orientate, reskill, and upskill around a human–machine collaboration framework to create a win–win scenario for industrial advancement. The building blocks of the innovative training and skilling programs are delineated. Early childhood education and K-12 education remain fundamental and mandatory for every citizen in the twenty-first century. In addition, diverse degree and non-degree options will provide avenues for citizens of the world to be lifelong learners. Non-traditional options such as employer-sponsored on-the-job training, seminars, self-study, and taking certificates from technology companies such as Microsoft are valuable opportunities.

Industry 4.0 leads society going through a digital transformation. This transformation centers on a vision of new education and learning programs that can effectively provide training, skilling, reskilling, and upskilling to the future-ready workforce. Both higher education programs and non-traditional options can offer opportunities to the workforce to advance their skill sets. To make this happen, business leaders, educators, and governments must proactively build facilities and programs for society to benefit from learning new skills, innovative knowledge, and advanced theories. When the university, government, and business organizations become members of the education alliance, they are part of the reskilling and upskilling collaborative ecosystem to train a future-ready workforce (Li, 2020).

Digital transformation has launched a global competitiveness pace which has initiated an instructional paradigm shift for learning and teaching. The US National Education Association (NEA), a founding member of the Partnership for the twenty-first century, is a viable advocator who encourages schools, districts, and states to infuse technology into education and provide tools and resources to facilitate that effort.[6] College degree programs are usually favorable for many people to upskill their capability and improve their credentials. In recent years, many universities have created new programs, such as data science and cybersecurity, to help the workforce strengthen their skills in critical thinking, complex problem solving, creativity, and communication (Li, 2020).

The COVID-19 pandemic accelerated the pace of automation. Employees and students swiftly acquired cloud technologies, video conferencing skills, and remote telework skills. Schools, retailers, banks, and many businesses are emerging from the crisis into a world of physical distancing workplaces that changed customer behaviors and preferences. Many people learn these skills over online programs, such as online workshops offered by their companies, YouTube videos, and self-training. Recovery is forcing organizations to re-imagine their operations for the new normal. Manufacturing companies are reconfiguring their supply chains and production lines using Industry 4.0 technologies. Service providers are adapting to digital operations and contactless services. Those changes will significantly affect the requirements for staff's skill sets because some face-to-face office roles may be replaced with a dramatic increase in home-based and remote working settings (Ellingrud et al., 2020).

Companies can improve and promote diverse approaches to address skill gaps. For example, they can build skills internally, retain their existing staff by supporting them to work on advanced degrees, reimburse their tuitions, or invite training experts to train their staff. Alternatively, companies can recruit new employees with the right skills. A hybrid approach, including using a skilled contract workforce to fulfill short-term needs while developing the necessary skills internally, is also feasible.

4.4.1 Upskilling and Reskilling through Higher Education

In recent years, universities have promoted many new programs to support the digitalization needs of Industry 4.0. As a result, employers expect to recruit new staff who have some basic knowledge of their particular specialism and additional business skills. Furthermore, business recruiters are increasingly looking for workers who have expertise in information technology. On the other hand, companies do expect to put all graduates through induction training as well as specialized training throughout their careers (O'Brien & Deans, 1996).

While completing a college degree in four years is a performance target of college education, Stanford University rolled out a new degree program called the Stanford2025 project. The Stanford2025 project allows students to extend their education over longer timeframes. One model is the "open loop university," where students can experience six years of higher education over their entire adult careers that provide an opportunity for them to blend their learning with life experience and provide value to the campus by returning as expert practitioners over several intervals to re-charge with new skills and knowledge. Another model is named AXIS FLIP, which prioritizes skill development and competency training over disciplinary topics. It is hypothesized that by applying these proposed degree models, students would constantly renew their skills and update their knowledge throughout their careers (Stanford2025, 2013). Yet, new student learning assessment measures and methods need to be developed to gauge the learning outcome.

Experiential Learning Experiential education serves as an integral part of a higher education degree program. While universities have established a student-centric effort to provide a hands-on and industry-oriented learning experience, they pay equal attention to developing students' ability to apply theories to practical problems. Internships are a valuable step to becoming a future-ready employee. By working in their chosen field and interacting with employers and customers before graduation, students are more precise about their career goals and become stronger candidates for future jobs (Li, 2020). Meantime, measurable rubrics should be created to assess students' problem-solving skills, critical thinking capability, and device operation skills during their experiential learning projects.

Universities are no longer solely emphasizing degree programs. Non-degree options have become part of higher education curriculum offerings. Many universities have added non-degree certificate programs to their catalog. For example, business schools in many countries have taken the lead in contributing to learning opportunities for a wide variety of individuals at different stages of their career paths. Fostering greater educational access requires business schools

[6] National Education Association http://www.nea.org/home/34888.htm. Accessed May 10, 2021.

to accelerate their move beyond the bounds of traditional degree-based education. Higher education will need to redefine itself within the campus, business community, and future-ready workforce management systems. As hubs of learning, universities need to partner with universities in other countries, industry clusters, and organizations within the public and private sectors. This approach helps achieve knowledge creation, innovation, and community-building missions (Gleason, 2018a, b; Li, 2020).

Technical and Vocational Colleges and Schools Germany, a leading manufacturing country globally and one of the best performing OECD countries in reading, mathematics, and science, redesigned the format of secondary vocational education for students to learn advanced skills for a specific profession. Most of Germany's highly skilled workforce has gone through a dual system of vocational education and training (VET) (Hockenos, 2018). In Germany, the VET programs have partnered with about 430,000 companies. Students learn skills through these programs that are easily transferable to an aspired profession. Once a company commits to an employee from one of these vocational schools, they have a commitment to each other, and about 80% of those companies hire students from the apprenticeship programs to get a full-time job. This educational system is very encouraging to young individuals because they can predict their career paths (Hockenos, 2018).

China, the largest manufacturing country, has a long tradition of training middle school or high school graduates in vocational and technical schools or three-year colleges that focus on a specific profession or skill set. China urgently needs a high-level skilled workforce to support its booming economy. Vocational schools and technical colleges became part of the economic development engine by training a job-ready workforce. By integrating theories into practices in their curricula, vocational education ensures that students will have the skills companies seek. For example, Wuxi Machinery Manufacturing School invested 6,000,000 yuan in building Numerical Control Technology Center, Advanced Electrical Center, and Automobile Testing Center to provide hands-on laboratories for students to learn advanced manufacturing technologies and skills (Wu & Ye, 2018). The ability to fully harness advanced technology and skills is vital to the full realization of Industry 4.0. However, many countries may not yet fully be able to execute in practice.

4.4.2 Reskilling and Upskilling through Non-Traditional Training

As digitalization grows in every workplace, it becomes increasingly essential to direct employees' time toward higher-value work. Professional associations recognize the need to upskill their members and workforce because upskilling is a requirement of many high-skilled professions. For example, university professors, nurses, accountants, and physicians must stay up-to-date on the knowledge of their professional area.

Professional Certificate Many professional societies offer certificates via exams. Association of Supply Chain Management (ASCM), the largest nonprofit association for supply chain professionals, offers globally recognized certification programs to help industry professionals upskill and reskill to respond better to supply disruptions, respond to demand variations, and manage supply chain risks.[7] The certification program serves the needs of both employers and supply chain professionals to be more competitive in today's global economy. As the pandemic caused a significant shift in consumer demand and put a spotlight on supply chain vulnerabilities, ASCM rolled out a new certificate in Planning and Inventory Management (CPIM) which supports supply chain professionals to develop the competencies and skills they need to successfully work across all functions of the supply chain and logistics to respond better to supply disruptions and demand variations and manage supply chain risk.

Re-certification Some professional jobs require regular re-certification to ensure that those who serve in a specific profession keep up with the advanced technology and the most current best practices. For example, nurse practitioners provide patient care in the middle of the Information Age, which means the amount of knowledge they need to know to do the job will double approximately every three years or even faster. Therefore, nurse practitioners certified by the AANP Certification Program must recertify every five years[8] by taking the appropriate examination or meeting the clinical practice and continuing education requirements established for recertification. In addition, there are various professional development and upskill options that a nurse practitioner can take. Typically, they can combine professional development, such as continuing medical education, enrolling in academic courses, sharing patient treatment experience with peers at professional conferences, publishing peer-reviewed journal articles, etc.

Company-Sponsored on-the-job Training The relationship between an organization and its people is a two-way street;

[7] https://www.ascm.org/?utm_medium=paid-search&gclid=EAIaIQobChMIgcSrqdC48QIVgZ-zCh2yuwHmEAAYASAAEgKO-vD_BwE

[8] https://www.aanpcert.org/recert/index; https://www.aanp.org/news-feed/aanp-and-aanpcb-your-membership-association-or-your-certification-board

therefore, the design phase of a future-of-work program should focus on a business's offer to its staff (Ellingrud et al., 2020). Companies need to develop clear and compelling value propositions to ensure their staff sees the benefits of acquiring new skills and learning new technology. For years, Japanese companies have created a valuable culture of on-the-job training programs to upskill and reskill their employees since they have a life-long employment tradition. Quality Circle is one of the well-known employee-supported upskill efforts. Quality Circle involves employees in decision-making and shifts the organization toward a more participative culture. The program trains people to be critical thinkers and problem solvers when they perform their roles on the job. A team leader who typically is a trained staff of the management team helps train circle members and ensures that things run smoothly. These quality circles generally meet four hours a month on company time, and members would be recognized if their suggestions for production improvement are adopted (Lawler & Mohrman, 1984).

In the dawn of Industry 4.0, digital links have increasingly replaced physical connectivity, and companies use more complex data networks in their operations. Greater inter-organizational collaboration is more possible than ever before (Xu, 2014). Using cloud-based software, any staff member in any geographical location can contribute to a design. To communicate more effectively, companies tend to use some standardized software such as Oracle, and Microsoft Office. Collaborating with third-party education providers to provide on-the-job training in information systems is a favorable choice to upskill employees. For example, as Microsoft added more functions to Excel spreadsheets, many companies quickly adopted new methods to run their operational business to interact with their business partners. University instructors are invited to business organizations to teach new Excel functions such as Power BI to help business employees stay current and effectively do business within the company and with their business partners.

Self-Study Open-Course Programs In recent years, self-study programs have been available online to support people who are willing to reskill or upskill their intellectual capability. MIT open courses[9] are open course programs that focus on "unlocking knowledge" and "empowering minds." MIT OpenCourseWare (OCW) is a free, publicly accessible, openly licensed digital collection of high-quality teaching and learning materials presented in an easily accessible format. Learners can take more than 2,500 MIT on-campus courses and use supplemental resources for knowledge advancement.

Technological innovation provides exciting opportunities and significant challenges for mature workers who are accustomed to routines, tasks, processes, and steps. These people tend not to like change. Yet, new technology is frequently updated at workplaces, regardless of employee's age. As a result, some technology companies started to offer self-study open-course programs. SAS, Inc. (Statistical Analysis System) provides self-paced free courses for users to upskill their coding capability using new interfaces and functions. Selecting from a variety of course topics created by the industry's top experts, SAS helps existing users and new users stay aware of the technologies that employers are looking for.

4.5 Obstacles to Reskilling and Upskilling

Some obstacles go along with the promising opportunity of upskilling and reskilling. After surveying 116 executives at large organizations in 2017, McKinsey reported that one in four business managers lacked a clear understanding of the impact of future automation and digitization on skill requirements. Nearly one in four said they lacked the tools or the knowledge to quantify the business case for efforts to reskill their workforces. And almost one-third thought that their current HR infrastructure would not be able to execute a new strategy designed to address emerging skill gaps (Ellingrud et al., 2020). Ellingrud et al. (2020) suggested that the reskilling challenge will be particularly acute in operationally intensive sectors, such as manufacturing, transportation, retail, and operations-aligned occupations. Those sectors and fields will experience a magnitude of change more significant than the industry average because the repetitive nature of many operational tasks makes them particularly suitable for automation or digitization. In addition, employees in these areas tend to have less education as compared with professional roles. Therefore, reskilling will be urgently needed to maintain the stability of a particular part of the middle class.

Other obstacles include employees' unwillingness to spend time and money to upskill or reskill themselves for the future. This attitude varied with older age group, who don't want change to occur in the workplace because their typical working day will be altered. Accessibility and affordability are challenges. Companies should create opportunities for their employees to learn, give them access to free Internet access and information, and provide financial affordability such as tuition support. Curricular alignment to Industry 4.0 skills is recommended as urgent action. The curriculum design needs to emphasize demand-driven skills and offer broad assessment criteria (Maisiri & Van Dyk, 2021).

Currently, displaced workers amid job transitions are seeking stronger safety nets. Yet, public funds have not been adequately allocated to support reskilling and upskilling.

[9] https://ocw.mit.edu/

The public sector will need to work with business organizations to invest in the future-ready workforce and tomorrow's jobs and decisively tackle long-delayed improvements to education and training systems.

5 Conclusions

World Economic Forum estimates that, by 2025, 50% of all employees will need reskilling due to adopting new technology. Five years from now, over two-thirds of skills considered important in today's job requirements will change. A third of the essential skills in 2025 will consist of technology competencies not yet regarded as crucial to today's job requirements. In this article, we have delineated top skills sought by the industry to realize Industry 4.0 and presented a blueprint as a reference for people to learn and acquire new skills and knowledge.

5.1 Contributions of the Study

The contribution of this study is three-fold. First, the study has pointed out the trend of technology advancement in the recent fifteen years. The reports on top 10 skills in 2015, 2020, and 2025 respectively, offer universities an insightful basis for developing reskilling and upskilling courses, programs, and seminars to train a future-ready workforce. Second, the analysis of workforce development in Africa, Asia, Europe, and Latin America indicates that new skills and technologies have been introduced much faster than a decade ago. Therefore, life-long learning is a reality and should be part of an organization's strategic goals. And finally, the education ecosystem in the Industry 4.0 era gives a guideline to individuals, universities, and companies that commit to reskilling and upskilling. This study stresses the importance of alignment between the skill needs of industry and higher education. The future-ready workforce should be mindful of diversity and respect different cultures and governance systems since Industry 4.0 focuses on an interconnected world via cyber-physical systems, IoT, and IIoT. We need to avoid thinking that one approach is superior to another. The goal of Industry 4.0 is to create prosperity for the working people in the world.

5.2 Future Research Directions

There are several avenues that this research can be extended. First, the relationships among higher education, labor markets, and industry should be strengthened. This study shows that, to a certain degree, skill shortages exist due to a lack of understanding of employers' perceptions, preferences, and expectations. Future research can promote collaboration among universities, industry, private companies, and the government to assess learning outcomes from curricula and extra-curricula, such as internships and industry field trips. Second, case studies can be conducted to understand how to establish a culture of life-long learning and ensure that the system is equitable. Third, comparative studies can be done to compare and address the challenges in different countries. So far, the scope of technology implementation that shapes different outcomes has not been well investigated and documented. Finally, our knowledge of developing skill-specific programs and program accreditation is insufficient and deserves more practice and research to improve.

Declarations

Conflict of Interest No conflict of interest.

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