Chapter

Behold the Fourth Industrial Revolution and How to Keep Pace with Workplace Competencies in an Ever-Changing World of Work!

Joseph Mukuni

Abstract

In recent years, the workplace has been changing constantly in terms of the nature of work and the processes, tools, and competencies required to support sustainable productivity and competitiveness of enterprises. The factors responsible for this change include massive technological innovations, demographic changes, and unforeseen circumstances such as the COVID-19 pandemic. These changes in work have exacerbated the alignment of skills supply and demand, putting pressure on providers of education and training to reform their curriculum content to include the in-demand technical and socioemotional competencies and the signature pedagogies best suited for the ever-changing curriculum content. This chapter identifies the Fourth Industrial Revolution with its attendant digital innovations as one of the key causes of change and proposes some pedagogical approaches to the teaching and learning of in-demand skills. The suggested pedagogies shift the burden of skills acquisition from the instructor to the learner through learner-centered methodologies that prepare students for lifelong learning, problem-solving, and interdisciplinary collaborative searches for solutions to unforeseen challenges associated with the Fourth Industrial Revolution innovations.

Keywords: digital skills, employability skills, portable skills, workforce, workplace

1. Introduction

It can be argued that one of the major purposes of education is to prepare young people for the world after school by giving them the knowledge and skills that will enable them to be effective participants in the socioeconomic activities of their nations. It is important, therefore, that schools and colleges align their curricula to the competencies matching their nations' socioeconomic activities. The socioeconomic activities for which schools and colleges should prepare students beyond schooling include working productively in formal or self-employment in the world of work. The goal of aligning curricula to the world of work is, however, easier said than done because of the nature of the gap between what is taught in schools and colleges and what is needed in the workforce.

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The challenges of minimizing the gap between the content of curriculum and the knowledge and skills demanded by industry and commerce include the difficulty of keeping pace with the rate of change on the demand side of education and training. The world of work is continuously in a state of flux, leading to constant adaptations and modifications of skill mixes in the repertoire of the workforce. The factors contributing to changes in work processes and their matching competencies include technological advancements, demographic changes, and unforeseen factors such as the onset of COVID-19 recently witnessed by the world. Some scholars have associated the changes in the workplace with the advent of the Fourth Industrial Revolution characterized by continuous adaptation and optimization of cyber-physical systems and the process required to operate and maintain them [1–4]. These changes and uncertainties in the workplace milieu put pressure on education systems desiring to be demand-responsive. This is because schools and colleges need to keep modifying curricula, reequipping learning stations, and retraining their staff to keep pace with the workplace changes and to maintain relevance and effectiveness in their role as suppliers of knowledge, skills, and dispositions needed by the workforce.

This chapter discusses the push factors of workplace change and proposes some pedagogical approaches to the teaching and learning of in-demand skills. The suggested pedagogies, which are suitable for teaching science, technology, engineering, and mathematics (STEM), shift the burden of skills acquisition from the instructor to the learner through learner-centered methodologies that prepare students for lifelong learning, problem-solving, and interdisciplinary collaborative searches for solutions to unforeseen challenges associated with the Fourth Industrial Revolution innovations. This chapter also proposes that the preparation of STEM-smart workforce should start at the primary school level rather than in later stages of education.

2. Push factors of workplace change

The world of work has witnessed technological changes since the onset of the First Industrial Revolution in the 1800s, with promises of joy to owners of capital and anxiety to the workforce. Owners of capital have welcomed technological advancements, expecting maximization of profits through mass production and a significant drop in labor costs and problems associated with industrial relations. The workforce, on the other hand, has felt threatened by the possibility of job insecurity, fearing that machines would take over work done by human beings. This section discusses the impact of technology on work, demographic factors affecting work in the changing world, and the impact of unforeseen change factors as witnessed recently when the world experienced the devastating COVID-19 pandemic.

2.1 Impact of technology on work

The nature of work has been changing because of several factors, including technological advancements, demographic shifts, and unforeseen circumstances [1]. Technological advancements have been driven by the desire to do less (e.g., by simply pushing a button), with little resources (e.g., fewer workers and a smaller wage bill), and to achieve more (e.g., mass production and greater profits). For instance, the First Industrial Revolution changed the nature of work significantly. The application of

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machines to manufacturing processes in the mid-to-late 1700s led to mass production of goods, a rise in the number of factories, and an increase in employment opportunities since machines needed operators and the mushrooming factories needed managers and workers. To contribute meaningfully to production and distribution of products and services in a changed world of work, the workforce needed a different set of skills from the agrarian skill sets that had characterized labor requirements before the Industrial Revolution.

The Second Industrial Revolution, like the one before it, had equally an impact on work because of the invention of electrical power, which enhanced mass production [5]. Enhanced mass production necessitated the reengineering of production lines for efficiency. One significant innovation was the change in the organization of work and chunking of tasks. As Beck [5] noted:

> *An improvement in production was the introduction of the assembly line by Henry Ford in 1914. On an assembly line, the complex job of assembling many parts into a finished product was broken down into a series of small tasks. It sped up production and reduced costs as each worker was only required to install one or two parts at their position on the assembly line. Ford would use the assembly line to speed up the production of automobiles in his factory in Highland Park, Michigan.*

The Third Industrial Revolution, according to Schwab [4], will be remembered for the use of electronics and information technology to automate work. The impact of the Third Industrial Revolution on work includes digitalization of work processes, which has brought about the importance of digital skills in workers' repertoire of competences [6, 7]. Today, most jobs are dependent on computers for planning, processing, and storing work, and dissemination of information, to the extent that it is difficult to imagine how work was done before the computer became a common feature at workplaces.

In 2016, Klaus Schwab, founder, and executive chairman of the World Economic Forum, announced the onset of the Fourth Industrial Revolution. He said:

> *We stand on the brink of a technological revolution that will fundamentally alter the way we live, work, and relate to one another. In its scale, scope, and complexity, the transformation will be unlike anything humankind has experienced before. We do not yet know just how it will unfold, but one thing is clear: the response to it must be integrated and comprehensive, involving all stakeholders of the global polity, from the public and private sectors to academia and civil society [4].*

The first three Industrial Revolutions changed the face of the workplace and significantly contributed to socioeconomic development through scientific innovations such as steam engines, electricity, and electronics. The Fourth Industrial Revolution has revolutionized the workplace further through advancements in digital as exemplified by robotics, quantum computing, artificial intelligence (AI), materials science, virtual reality, three-dimensional (3D) printers, intelligent manufacturing, energy storage, the Internet of Things (IoT), genetic engineering, and biotechnology [2, 3]. A term associated with increased use of technology for purposes of work is digitalization of the workplace. Workplace digitization has been explained by Sheng et al. [8] as "electronic tools, automatic systems, technological devices, and resources that generate, process, or store information in the form of binary code" (p. 198). This digitalization trend has made it almost imperative for workers to have digital skills because most jobs require use of computers and digital knowledge and skills to operate computer-controlled machines [9].

The advent of the Fourth Industrial Revolution has not been without anxiety among some workers. The advancements in electronics and digital tools have raised fears about an expected negative impact on the labor market. For example, it has been noted that:

> *Most observers seem to agree that job destruction is likely to accelerate under the impression of current technological changes. In contrast, little is known about the potential for the creation of new jobs. For such new jobs to appear, many comment on the need for new markets to be developed and regulated, in particular in the green economy, care and personal services sectors, or an augmented public sector in areas where currently no profitable activities exist. The fear is that this process might not happen fast enough. Therefore, the number of jobs might fall faster than the global labour force when existing jobs are substituted by automation and other systems operated by artificial intelligence. In other words, machines, robots and computers will increasingly have an absolute advantage over labour and not only a comparative one ([10], p. 8).*

One study [9] reported from a review of literature that the use of robots at workplaces has led to the replacement of 1.6 manufacturing workers per robot and that by 2030, robots will, worldwide, displace 20 million manufacturing jobs. There seems to be a legitimate concern about some serious unintended consequences of the Fourth Industrial Revolution, despite the good intentions of advancements in technology. These concerns affect the morale and productivity of the workforce and should be catered for, along with the rest of the employability skills, when drawing up the list of competences that need to be addressed in the education and training of workers in response to the impact of the Fourth Industrial Revolution.

2.2 Demographic challenges

Concerns about the possibility of technology having an absolute advantage over human beings at workplaces, and the changed nature of competences that workers in the Fourth Industrial Revolution must have for them to contribute effectively to productivity and to maintain their jobs despite advancements in technological tools, are topics worthy of note by workforce development practitioners. To be added to these trending topics is the issue of workforce demographic challenges relating to technology use, particularly with reference to older workers. Some studies have found that older workers generally have difficulties with the use of technology [11, 12], especially older workers of color who have little or no access to computers at home.

The challenges of lack of or little use of computers among older workers do not apply to all older workers. Some older workers are computer literate [12]. This, however, does not belittle the impact of digitalization on older workers. Because of workplace digitalization, some older workers have had to make a serious decision about whether to retire early or to acquire the digital skills needed for their jobs [13].

The discourse about demography and digital skills is not only about the older workers' digital competences or lack of savviness. Young workers too are impacted by the skill demands of the Fourth Industrial Revolution. The myth that all young people, as digital natives, are computer literate has been debunked [14]. Studies have shown that a significant number of young people, particularly those from underprivileged homes, either lack the needed digital competences or have difficulties with applying their digital knowledge and skills to real-world work situations [15, 16]. Furthermore, studies have shown that young people's use of social media can cause harm to them, including cyberbullying, invasion of privacy, identity theft, social isolation, and mental health issues [17–20]. These serious side effects can be mitigated by providing workforce development that includes not only digital literacy skills but also strategies for coping with (or preventing) the risks associated with digital tools and social media platforms.

2.3 Unforeseen challenges

The onset of the COVID-19 pandemic recently taught the world of work to be aware that no matter how much workforce development programs may prepare workers for their tasks and life at work, nature has the final word. Quite unexpectedly, the COVID-19 pandemic befell the world and dealt a serious blow not only to the workforce but also to the nature of work across the globe [21–24]. The impact on the workforce included sickness, death, mental health issues, job insecurity, burnout, and stressful exhaustion [22, 25–27].

Thanks to COVID-19, the nature of work has changed, arguably forever. For instance, the boundary between work and home has practically disappeared because of the shift to remote work [26]. Performance of work is no longer restricted to a workstation in a specific locality. Most jobs are now done remotely. Because of this work-at-home trend, the pandemic has accelerated the Fourth Industrial Revolution by forcing workplaces to adopt virtual platforms and digital tools best suited for remote work [28] to avoid total shutdowns. In a sense, the timing of the Fourth Industrial Revolution can be seen as a blessing in disguise. One can hardly imagine how much greater the impact of COVID-19 would have been without the advancements in digital technologies characterizing the Fourth Industrial Revolution.

3. Pedagogical implications

Just as the First Industrial Revolution had an impact on schooling as we know it today [27], the Fourth Industrial Revolution has educational implications. Before the Industrial Revolution of the 1800s, schooling was mainly for the privileged few who were being prepared for white collar jobs. With the mushrooming of factories resulting from the First Industrial Revolution, factory owners needed skilled labor, which was in low supply, and this led to the proliferation of vocational education and training in the school systems [28]. Initially, the vocational schools were private because:

> *As a logical outgrowth of the Industrial Revolution and the subsequent specialized worker, many industries attempted to give their workers training in order to increase efficiency and thus increase their productivity. Therefore, many industries set up factory schools and one of the first was that of Hue and Company of New York City which, in 1872, set up a plant school for the purpose of training apprentices in the skilled trades and in particular the machinist trade ([29], p. 10).*

The need that was felt in the 1800s to have human capital that would contribute to efficiency and therefore productivity leveraging the advancements in technology is again emerging in the wake of the Fourth Industrial Revolution.

The pedagogical implications of the Fourth Industrial Revolution evolve around two questions: (a) *Curriculum content:* What knowledge, skills, and dispositions should workforce development institutions emphasize to respond to the needs of the changing nature of work? (b) *Pedagogical approaches:* What are the best pedagogical approaches for workforce development in the era of the Fourth Industrial Revolution?

3.1 Curriculum content

Much has been written about the workforce competences demanded in the world of work, given the fast-changing nature of work driven by technological advancements. As far back as 2010, an academician had perceptively foretold the complexity and unpredictable nature of work in the future:

> *The process of managing decisions and solving social scientific problems in contemporary democracies is growing ever more complex. At least 70% of U.S. jobs now require specialized knowledge and skills, as compared to only 5% at the dawn of the century... Furthermore, the nature of work will continue to change ever more rapidly... Thus the new mission of schools is to prepare students to work at jobs that do not exist, creating ideas and solutions for products and problems that have not yet been identified, using technologies that have not yet been invented ([30], p. 2).*

That future which Darling-Hammond [30] foretold has now come and is still unfolding. As she predicted, the workforce is faced with the challenge of coping with tasks and technologies for which no schooling ever prepared them to handle. Little wonder that the general conversation about Fourth Industrial Revolution skills [31–38] seems to focus more on portable employability skills such as the following in addition to technical digital skills:

- Problem-solving skills
- Creativity and originality
- Stress tolerance and flexibility
- Critical thinking skills
- Emotional intelligence
- Judgment and decision-making
- Cognitive flexibility
- Communication skills
- Cognitive load management
- Computational thinking
- Technology design and programming skills

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- Lifelong learning skills
- Cross-cultural competency
- Virtual collaboration skills

These skills are portable across disciplines because they are generic. Workers who have these skills are likely to cope with the ever-changing nature of work and the new technologies that drive the work because they will have the right attitude toward change, the resilience to withstand confusing and ambiguous work situations, the cognitive aptitude to learn new skills, the communication and people skills needed to enable them to interact with other people despite the tendency of technology to promote isolation and individualism, and the preparedness and ability to solve problems arising from the nature of machines, tasks, and the social or physical environment at the workplace.

3.2 Pedagogical approaches

One educational phrase that came into popular usage during the era of the most recent industrial revolutions is STEM, or in full, Science, Technology, Engineering, and Mathematics. In searching for the pedagogies best suited for the Fourth Industrial Revolution, we should therefore look at STEM pedagogy.

There are several features that define STEM signature pedagogy. Key among them are student-centered methodologies, promoting problem-solving, encouraging teamwork, fostering critical thinking, and learning by doing. These features are seen in the following STEM approaches to teaching and learning:

a. *Problem-Based Learning (PBL):* Savery [39] described PBL as “an instructional (and curricular) learner-centered approach that empowers learners to conduct research, integrate theory and practice, and apply knowledge and skills to develop a viable solution to a defined problem. Critical to the success of the approach is the selection of ill-structured problems (often interdisciplinary) and a tutor who guides the learning process and conducts a thorough debriefing at the conclusion of the learning experience” (p12). In this approach, students are given a real-world problem to solve. Working in pairs or groups, students analyze the problem and come up with solutions. This process makes them engage and develop higher-order cognitive skills, critical thinking, creativity, and teamwork skills. The teacher’s role is not that of a dispenser of knowledge but a provider of authentic tasks and scaffolding while observing and monitoring students as they work.

b. *Inquiry-Based Learning (IBL).* According to Pedaste et al. [40], IBL is “an educational strategy in which students follow methods and practices similar to those of professional scientists in order to construct knowledge” (p. 48). In this method, learning starts with students raising a question to be investigated. Then they conduct an experiment using the right tools and procedures and observe the results. This is followed by information synthesis or report writing after which students share their findings with the rest of the class. The last stage in this process is reflection, which enables students to look back at what they have done and learned during the inquiry.

c. *Project-Based Learning (PjBL):* PjBL has been described [41] as "an inquiry-based instructional method that engages learners in knowledge construction by having them accomplish meaningful projects and develop real-world product" (p. 2). In PjBL, students may work individually or in groups to create a real-world product. They have the autonomy to choose the procedure for developing a solution to an authentic problem. The teacher plays the facilitation role that encourages students to discover on their own what works and what does not work in coming up with a real-world product. This helps students to develop creative skills that are needed in the innovative era of the Fourth Industrial Revolution.

d. *Challenged-Based Learning (CBL):* "Challenge Based Learning is an engaging multidisciplinary approach to teaching and learning that encourages students to leverage the technology they use in their daily lives to solve real-world problems. Challenge Based Learning is collaborative and hands-on, asking students to work with peers, teachers, and experts in their communities and around the world to ask good questions, develop deeper subject area knowledge, accept and solve challenges, take action, and share their experience" ([42], p. 1). In this approach, students select a challenge and the method, materials, and tools that they will use to overcome the challenge. This approach builds on the other approaches mentioned above. Its benefits include development of critical thinking skills, problem-solving skills, creativity skills, and collaborative skills. Interdisciplinary collaboration mimics the real-world practice in which experts work across disciplinary boundaries to complete tasks.

All the approaches discussed above are based on student-centered methodologies in which students are in charge of their own learning. This prepares them for future workforce situations that require them to be lifelong learners.

3.3 STEM talent pipeline

It is generally agreed that investing in STEM in any country is important because STEM is a key element in promoting scientific innovations and carrying out the industrial tasks whose processes have been transformed by recent inventions [43, 44]. What is not mutually understood is the need to start this investment at primary school level instead of later stages of education (secondary school level and higher education) where some policymakers tend to focus. Primary school education is unarguably a foundational building block upon which the rest of the formal education process rests. Investment in STEM should, therefore, begin at the primary school level, leveraging the characteristics of early child development that present opportunities for laying a foundation for STEM education. By nature, primary school children are curious and want to discover the workings of the natural world. This curiosity and motivation to explore the world around them should provide a natural starting point for STEM education and awaken a sustained interest in STEM all through secondary school and college, leading to an increased supply of STEM talent in the workforce.

There are, however, some factors that work against initiating STEM education at primary school level [45]. The key constraint is insufficient funding for retraining of teachers in STEM signature pedagogies and for supply of the necessary teaching/learning materials. The other major constraint is the attitude of teachers who view STEM as an unwanted challenge to their comfort zones and old ways of doing things. These challenges are surmountable and the reward for overcoming them is the

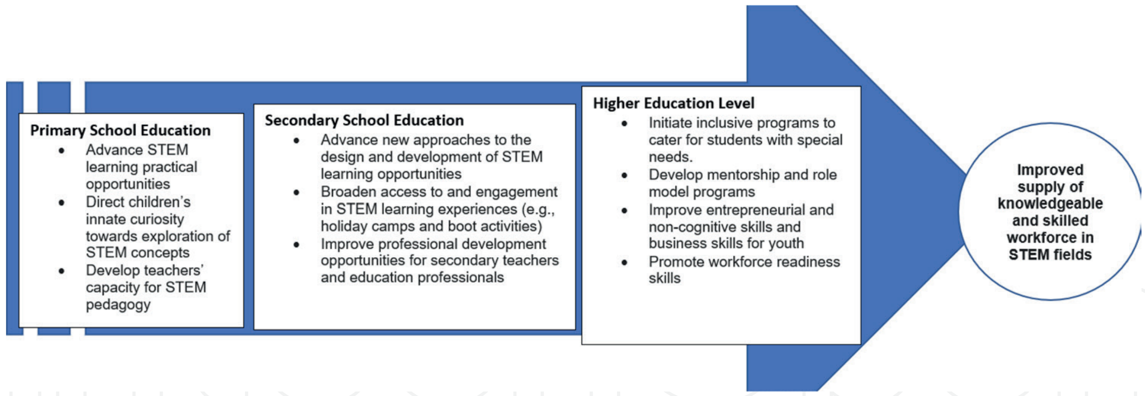

Figure 1.
Science, technology, engineering, and mathematics (STEM) pipeline flow from primary school to the world of work.

existence of an innovative STEM-educated workforce comprising movers and shakers needed for supporting innovations of the Fourth Industrial Revolution.

The diagram given in **Figure 1** describes the STEM talent pipeline from primary school to the world of work.

3.3.1 Primary school education

The primary school level lays the foundation on which the rest of the levels of education are built. It is therefore important that the seeds of STEM be planted at this level. Activities for promoting STEM at this level should include:

- Advancing STEM learning in practical opportunities for students to see applications of science, technology, engineering, and mathematics in everyday life, including children's games.

- Directing children's innate curiosity toward exploration of STEM concepts using games.

- Developing teachers' capacity for STEM pedagogy through exposure to STEM pedagogies during preservice teacher education and in-service programs.

3.3.2 Secondary school education

Promotion of STEM at the secondary school level should build on the foundation laid at the primary school level. Activities for encouraging and nurturing motivation for STEM at this level should include the following activities:

- Advancing new approaches to the design and development of STEM learning opportunities.

- Broadening access to and engagement in STEM learning experiences (e.g., holiday camps and boot activities).

- Improving professional development opportunities for secondary teachers to enhance their theoretical knowledge of STEM pedagogies and their capacity to translate theory into practice in classrooms, laboratories, and experiential learning sites.

3.3.3 Higher education level

At higher education level, the following strategies should be applied:

- Developing mentorship and role model programs by inviting subject matter experts from industry to give talks to students and to establish mentorships with students.

- Improving entrepreneurial and noncognitive skills and business skills through, for example, encouraging students to establish student-led businesses under the guidance of businesspersons/entrepreneurs.

- Promoting workforce readiness skills through internships and research projects that require students to investigate the employability skills (both soft skills and hard skills) demanded by industries.

- Supporting professional development for STEM teachers at primary and secondary school level.

4. Conclusion

The world of work is constantly changing, making it necessary for workforce developers in schools and colleges to review the content and pedagogy of knowledge, skill, and attitude development periodically for learning institutions to remain relevant to the demand side of education and training. This chapter has explored the factors that have in recent years contributed to changes in work processes and their matching competencies. These factors include technological advancements, demographic changes, and unforeseen factors such as the onset of COVID-19 which was recently witnessed by the world. Some scholars [1–4] have associated the changes in the workplace with the advent of the Fourth Industrial Revolution characterized by continuous adaptation and optimization of cyber-physical systems and the process required to operate and maintain them. In response to these factors of change, this chapter has proposed a pedagogical approach to workforce development. The proposal is that suppliers of knowledge, skills, and dispositions should adopt student-centered methods that have characterized STEM signature pedagogies, such Problem-Based Learning, Project-Based Learning, Inquiry-Based Learning, and Challenge-Based Learning. These approaches promote the development of employability skills (such as problem-solving, critical thinking, teamwork, and creativity) which are in demand in workplaces during the era of the Fourth Industrial Revolution. This proposal for changing the traditional teacher-centered pedagogical approaches to student-centered methodologies entails systemic changes among training providers, including periodic professional development, adequate funding for equipment and materials, strengthening quality assurance, establishing strategic linkages with industries, and rewarding instructional best practices in ways that are meaningful to teachers.

Author details

Joseph Mukuni
Virginia Tech, Blacksburg, USA

*Address all correspondence to: mjoseph7@vt.edu

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